TETRA TECH

MEMO

To:	Julia Mancinelli, Environmental Manager, Innergex Renewable Energy, Inc.
Cc:	Eddie Park, Project Developer, Innergex Renewables USA LLC
From:	Dr. Bob Pearson, Senior Project Manager, Tetra Tech
Date:	Friday, December 14, 2018
Subject:	Heat Island Effect in Context to the Proposed Paeahu Solar Project, Maui County, Hawaii

Innergex Renewables USA, LLC (Innergex) has proposed to build the Paeahu Solar Project (the Project) located within the northwestern portion of Tax Map Key (TMK) 2-1-008:001. The solar arrays and associated infrastructure would utilize approximately 200 acres of Ulupalakua Ranch–owned land located east of the Maui Meadows neighborhood in Wailea, Maui. The Project would have a generating capacity of 15 megawatts (MW), an area designated for a 60 megawatt hour battery energy storage system, and an approximately 0.5-mile overhead generation-tie line that would interconnect the Project to the Maui Electric Company grid at the existing Auwahi 69-kilovolt substation.

Solar energy is the conversion of sunlight into usable energy forms. The sun's rays transmit light energy, in the form of photons, which can be converted to electricity using certain materials that naturally release electrons when exposed to light. These materials are contained within the photovoltaic solar panels. Innergex plans to install conventional crystalline-silicone solar panels at the Project, which have the capability to convert 19 percent of the incoming sunlight to electricity. Another roughly 10 percent of the sunlight will be reflected by glint and glare from the transparent covers on the solar panels. The remaining approximately 70 percent of the solar energy will be absorbed by the panels and converted to heat. Some studies have observed the creation of a "heat island effect" over a large utility-scale solar project (Barron-Gafford et al. 2016). The Maui Meadows community has expressed concern regarding the potential for the Project to induce a "heat island effect" that would raise the ambient air temperatures around the solar facility by 5 to 7 degrees. The following information has been provided to address these concerns as they relate to the proposed Project.

The study conducted by Barron-Gafford et al. (2016) compared temperature patterns measured at a solar farm in the Tucson, Arizona area, an undeveloped natural desert area near the solar farm, and a nearby asphalt parking lot. The study observed that the temperature over the solar panels during the day is about the same as over the nearby desert. However, the study also found that the land beneath the solar panels was heated by the panels during the day and retained heat and stayed warmer than the natural (undeveloped) desert at night.

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This study was done within the University of Arizona Science and Technology Park Solar Zone in Tucson, Arizona. The findings from this study are specific to a solar facility constructed in the Tucson desert where the ground was mass graded, and all vegetation was removed. The Tucson solar site differs from the proposed Project site in several ways. First, the proposed Project will not be mass graded. Most of the native vegetation would remain, thus preserving the natural heat gain and storage characteristics of the soils beneath the Project site, which would be similar to the natural conditions outside of the Project site. Second, the Tucson area is a broad desert valley with no surface waterbodies nearby. Accordingly, the local meteorology in Tucson is quite different from that in Maui, which is adjacent to the Pacific Ocean and has natural offshore and onshore winds.

Another recent study conducted by Li et al. (2018) was recently referenced in a LA Times article (Kaplan 2018) titled "Wind and solar farms can make their own weather, including extra rain over the Sahara." The Li et al (2018) used a climate model to show that large-scale installations of wind and solar farms covering the Sahara Desert could lead to local temperature and precipitation increase. However, the study also states that wind and solar farm impacts are dependent on the specific location and spatial distribution and that assessment of impacts from smaller scale wind and solar farms at specific locations would require further study. The area of the Sahara Desert is approximately 11,250,000 times the size of the Paeahu solar project. Additionally, the study was done in context to the desert environment. Therefore, the findings from the Li et al. (2018) study are not applicable or representative to the Project.

The following provides a brief explanation of the meteorological patterns that currently occur in the Wailea area and how these patterns would interact with the warming of the Project solar panels.

During the day, the Project's solar panels will heat up and warm the air above and below the panels. As the air above the panels will be warmer than the surrounding air, a chimney effect will occur (see Figure 1, label #3), and the warm air near the panels will rise into the atmosphere until it cools enough to reach the temperature of the surrounding air (see Figure 1, label #4). The cooler air over the ocean to the west will flow onshore toward the Project (see Figure 1, label #2) and up the surrounding hillside to replace the warm air that rises from the land surface. This chimney effect occurs naturally in the existing conditions of the Project area as the sun warms up the ground surface during the day causing the air to warm and rise and flow eastward uphill. This situation is typical during the day in ocean beach environments where cooler ocean air blows onshore from the water to replace the rising air over the warmer land surface (NWS, 2018). Due to this naturally occurring chimney effect, daytime temperatures should not be noticeably different at or near the Project area than they are currently in the natural environment.

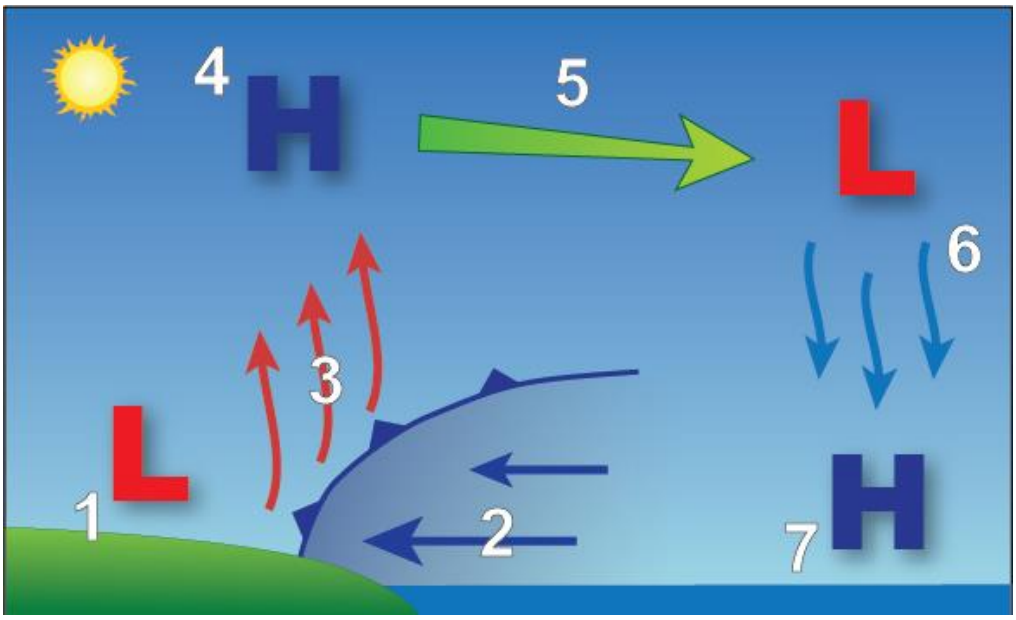

Figure 1. Daytime air movement in a coastal region (NWS, 2018)

Near and after sundown, the solar panels and the soil surface will cool to the temperature of the surrounding air. The soil surface beneath the panels that was shaded during the day will cool during the night and the air over the land surface will also cool and will become denser than the warmer air over the water. When the land surface is cooler than the ocean water surface, the cool air will flow downhill to the beach and out over the water (Figure 2). This offshore flowing wind during the night is a natural occurrence on beaches around the world.

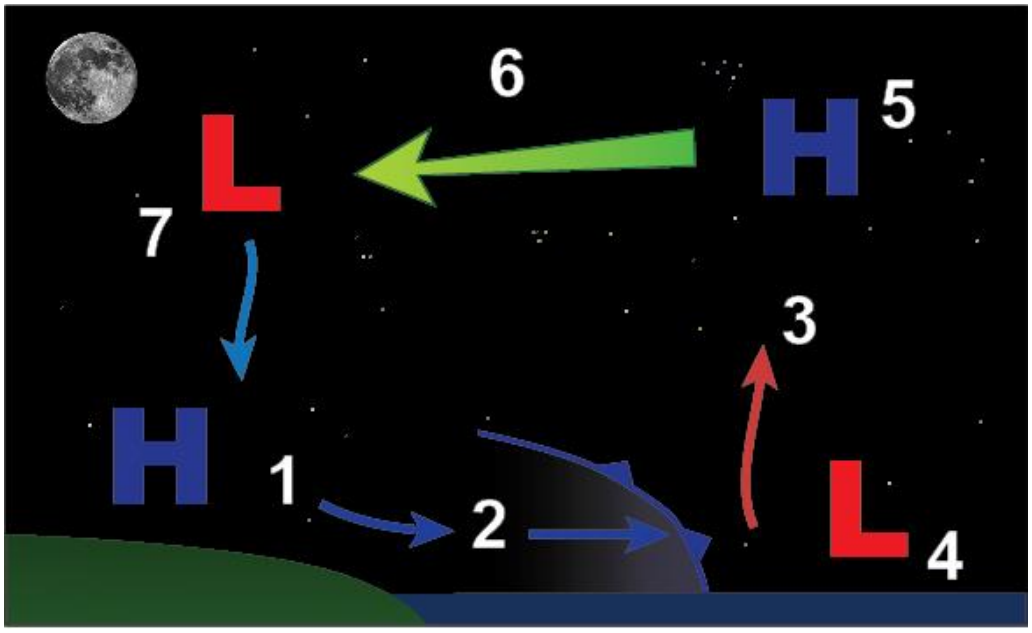

Figure 2. Nighttime air movement in a coastal region (NWS, 2018)

It is possible that the daytime heating of the Project panels could warm the soil beneath the panels causing the ground to stay warmer for longer into the evening than the air above the natural (undeveloped) ground and thus delay the onset of the cool, downslope winds flowing toward the ocean at night (Figure 2, label #2). During the transition period from upslope to downslope winds (typically occurring around sunset), any remaining air heated from the soil beneath the panels will raise straight upwards as the soil cools to the ambient air temperature. As the area beneath the panels would be relatively small (less than 200-acres) and as the Project is situated on the west-facing slope of Mount Haleakala that climbs to an elevation of over 8,000 feet on the ridge east of the Kula Highway and includes many square miles in area, the nighttime downslope winds that naturally occur in this area (see Figure 2, label #2) would still occur from the higher terrain and would mix with and dilute any remnant warm air beneath the solar panels. Thus, even if there was a small heat island effect at the Project area, the upslope and downslope winds that naturally occur on the southwestern side of Maui (off the southwest-facing slopes of Mount Haleakala) would overwhelm the heat island beneath the solar panels and the results would be cool air crossing the Maui Meadows area in the evening. The area of the Project is simply too small in relation to the area of the southwestern slope of Mount Haleakala to have a significant impact on the natural upslope and downslope air movement in the Wailea area.

In summary, the construction and operation of the Project will not significantly change this natural diurnal flow of air back and forth across Maui Meadows. Even if the solar panels warm the underlying soil beneath the solar panels more than the natural ground during the day, the existing cool, downslope winds at night will dilute any warm air that is temporarily released from the cooling ground below the panels and carry this heat toward the ocean in the naturally occurring offshore flow.

References:

Barron-Gafford, G. A., R. L. Minor, N.A. Allen, A.D. Cronin, A.E. Brooks, and M.A. Pavao-Zuckerman. 2016. The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures. *Scientific Reports* 6: 35070; doi: 10.1038/srep35070 (2016).

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Note:

This memo was authored by Dr. Robert Pearson, a nationally recognized expert concerning environmental issues in the electric utility industry. Dr. Pearson has over 42 years of experience in environmental and technical engineering, regulatory review and assessment, preparation of industrial compliance policy, and environmental consulting. See Attachment A for a copy of Dr. Pearson's Curriculum Vitae (CV).

Attachment A. Dr. Pearson's CV

ROBERT L. PEARSON, Ph.D., PE
Principal

Education

Ph.D., Remote Sensing of Natural Resources, Colorado State University, 1973.
M.Sci., Remote Sensing of Natural Resources, Colorado State University, 1971.
Professional Geophysical Engineer, Colorado School of Mines, 1968.

Professional Registration

Registered Professional Engineer in Colorado (12582)

Experience

Principal, Broomfield Environmental LLC, 2015 to present
Senior Project Manager, Tetra Tech, Denver, CO, 2014 to present
Vice President, Principal Technologist, Environment and Nuclear Division CH2M HILL, Denver, Colorado, 2000 to 2014
Project Manager, URS-Radian, Denver, CO, 1994-2000.
Senior Staff Scientist, Radian Corporation, Denver, CO, 1992-1994.
Administrator, Environmental Affairs, Public Service Company of Colorado, Denver, CO, 1979-1992.
Senior Environmental Engineer, Public Service Company of Colorado, Denver, CO, 1973-1979.
Project Geophysicist, Chevron Oil Company, Geophysical Division, Los Angeles, CA and Houston, TX, 1968-1969.

Appointments

Colorado Water Quality Control Commission, 1983. Appointed by Governor Lamm for a three year term, confirmed by the Colorado Senate.
Colorado Plant Operator Certification Board, 1984. Appointed by Governor Lamm for a three year term.
Colorado Water Quality Control Commission, 1986. Appointed by Governor Lamm for a three year term, confirmed by the Colorado Senate.
Colorado Plant Operator Certification Board, 1987. Appointed by Governor Lamm for a three year term, Chairman, 1986-89.
Colorado Water Quality Control Commission, 1989. Appointed by Governor Romer for a three year term, confirmed by the Colorado Senate, Chairman 1988-91.
Governor's Blue Ribbon Panel on the Future of Health Care in Colorado, 1989. Appointed by Governor Romer.
Colorado Center of Environmental Management, 1992. Appointed by Governor Romer.

Robert L. Pearson, Ph.D., PE

Grand Canyon Visibility Transport Commission, Public Advisory Committee, 1992. Appointed by Governor Romer.
National Coal Council, 2006 to 2014. Appointed by US Secretary of Energy Steven Chu.to this Advisory Committee for the US Secretary of Energy.

University Teaching Experience

Taught master's level course titled Air Quality Planning and Policy, URP 6686-002, Department of Urban and Regional Planning, College of Architecture & Planning, University of Colorado at Denver, 1995 to 2003.
Faculty Advisor, Regis University, 1996

Fields of Experience

Dr. Pearson is the Principal in the environmental consulting firm Broomfield Environmental LLC. He is also currently a senior project manager for Tetra Tech in their downtown Denver office. Previously he served as a Vice President and Principal Technologist in the Environment and Nuclear Division of CH2M HILL in their Denver office. Before that he was a Project Manager in the Denver technical staff of Radian International responsible for the technical conduct of research and analysis projects for these clients. He has over 42 years of experience in environmental and technical engineering, regulatory review and assessment, preparation of industrial compliance policy, and environmental consulting. He has proven ability to work with clients to assess regulatory programs, define needs, and develop programs to satisfy those needs. His program administrative experience includes projects in electric and magnetic fields, air pollution control and assessment, water quality control, environmental permitting, and environmental research and development. Dr. Pearson is a nationally recognized expert concerning environmental issues in the electric utility industry. He has also served as a state water quality regulatory commissioner and commission chairman appointed by the governor, as well as a member and chairman of a water quality operator certification board, also governor appointed.

Electric and Magnetic Field Health Effects

- Managed utility company participation in two state of the art epidemiological research studies on the relationship between electric power lines and the occurrence of childhood cancer. These studies were done in Denver by Wertheimer and Leeper in 1978 and Savitz et al. in 1985. Much of the data required for the studies were provided from company data files and the overall design and execution of both studies was critiqued for its correctness and appropriateness.

- Provided electric and magnetic field (EMF) analysis and testimony for a 115 kV underground electric transmission project In Denver which had been stalled by

community opposition. As a result, the concerns of the citizens were allayed and the project was allowed to be constructed and placed into operation on schedule.

- Provided EMF analysis and expert testimony to governmental bodies for an overhead electric transmission project being relocated due to construction of the new Denver International Airport. The EMF concerns raised by the governmental bodies were reduced to a level allowing them to approve the project to be built on schedule.

- Chaired the EMF Health Studies Task Force of the Electric Power Research Institute. This industry advisory committee directs the EMF health studies research program of the Institute which is the largest such basic EMF research program in the world.

- Served as Vice Chairman of the Electric and Magnetic Fields Task Force of the Edison Electric Institute. This trade association industry committee of the investor-owned electric utilities in the United States provided policy preparation and issue management for this largest sector of the American electric utility industry.

- Participated in the organization and conduct of annual EMF scientific meetings for the Electric Power Research Institute (EPRI). These annual meetings are the principle informational meetings for representatives of the electric utility industry.

- Provided analysis and expert opinion on the EMF effects of a proposed Regional Transportation District light rail transportation system. This system, which is electrically powered, runs through several residential neighborhoods as well as commercial and industrial districts in the Denver area.

- Analyzed and provided expert opinion on a proposed university high energy physics facility. This facility proposed to be constructed on the campus of the University of California at Los Angeles (UCLA), will house state of the art high energy particle accelerators. The analysis provided information regarding the exposure to the surrounding neighborhood of magnetic fields from the facility as well as within the facility laboratories.

- Analyzed and provided expert opinion on a proposed electric cogeneration facility. This facility, also to be constructed on the campus of the UCLA, will provide electric power to the University. The analysis provided information regarding the potential interference with adjoining telephone switching equipment, as well as exposure to workers in nearby offices.

- Served as co-principal investigator and Project Manager of a study to investigate the "wire code paradox", sponsored by the Electric Power Research Institute. The apparent paradox was revealed when earlier EMF epidemiological studies done in Denver and elsewhere demonstrated a relationship between a surrogate measure of magnetic fields exposure, the wire code, and the occurrence of childhood cancer. Actual measures of magnetic fields showed no such relationship. The study investigated the nature of the

wire code paradox and to determine if the wire code is related to other parameters of the neighborhood such as its layout or of the house such as its age where the child lived. Several papers on the design and status of this project were presented to the Annual DOE/EPRI Contractor's Review Meetings and Annual Meetings of the Bioelectromagnetics Society.

- Served as co-principal investigator and Project Manager of a study to investigate the feasibility of conducting an epidemiological investigation of children living in very high current configuration residences, sponsored by the Electric Power Research Institute. This study explored the feasibility of identifying children who live near larger power lines who could be surveyed for their incidence of contracting various forms of cancer including leukemia.

- Served on the study team evaluating the environmental impacts of the proposed Seattle East Link Light Rail System segment from Seattle to Belleview WA, the Federal Way segment from the SeaTac Airport to Federal Way and the downtown Tacoma circulator. My role was to evaluate the exposure to EMF for both passengers on the train as well as members of the public long the right of way. I also reviewed the potential for interference with sensitive electronic equipment in buildings near the ROW as well as pipelines corrosion in underground utilities along the ROW.

- Served on the study team evaluating the environmental impacts of the proposed Minneapolis Metro Southwest Light Rail Train extension segment from downtown Minneapolis to Eden Prairie, MN. My role was to evaluate the exposure to EMF for both passengers on the train as well as members of the public long the right of way. I also reviewed the potential for interference with sensitive electronic equipment in buildings near the ROW as well as pipelines corrosion in underground utilities along the ROW.

- Served on the study team evaluating the environmental impacts of the proposed California High Speed Train System segment from Modesto to Fresno CA, the segment from Modesto to Sacramento and from Fresno to Bakersfield. My role was to evaluate the exposure to EMF and electromagnetic interference for both passengers on the train as well as members of the public and communications systems along the right of way.

- Served as Project Director of an assessment of the magnetic fields to be generated by the proposed high speed electric rail system to be built in Texas. This project determined the background levels of magnetic fields and the field levels which will be generated by the transit system when it is placed into service. Areas which will be exposed to an elevated magnetic field as a result of the operation of the transit system were determined. These magnetic field levels were then screened to determine if existing occupational or environmental guidelines or standards will be exceeded and if so what health implications there may be given the current scientific knowledge on the subject. As a portion of this project, measurements were made of the magnetic fields produced by the Spanish high speed rail train, the AVE, which operates between Madrid and Seville. This rail system is identical to the system proposed to be constructed in Texas. Measurements were made

both on the train as well as along side the tracks and at a power substation which supplies electricity for the AVE rail system.

- Conducted two surveys of magnetic fields produced by 25 kV distribution power lines for an electric utility in Granada, Spain. The utility had received two requests to relocate two primary voltage distribution power lines, one from the local government and one from a group of concerned neighbors. Measurements were made of the magnetic fields produced by each of these lines which demonstrated the magnetic fields to be very low. Reports were produced for the utility for presentation to the city government and the group of concerned neighbors.

- Representing two electric utilities in Colorado at public meetings on the construction of new 115 and 230 kV electric transmission lines to be built to serve eight separate areas in Colorado and New Mexico. Presented information on the expected magnetic field levels to be produced by the transmission lines and the broader issue of the status of scientific knowledge on human health effects of electric and magnetic fields. That information was specifically requested by the public to be presented by a recognized expert in the field other than an employee of the utilities.

- Modeled the magnetic fields in the transmission switchyard and in an underground power transmission cable at the Protrero Power plant in the Bay Area of California. The project is to add a seventh unit to the power plant. The California Energy Commission requested that the modeling be done as part of the environmental impact analysis for the plant.

- Served as Principle Investigator of an EMF research project on the Denver area for the Electric Power Research Institute. The project measured the voltages induced in grounded water pipes and electric neutrals along with magnetic fields in the homes and wire codes from nearby power lines in 191 homes selected from the Denver metropolitan area.

- Testified as an expert EMF witness for Tri State Generation and Transmission in the Eighth District Court in Raton, New Mexico, January 2006. The issue was a condemnation proceeding: Tri-State Generation and Transmission Association, Inc. v. Faver, King, Sierra Grande, and Spanish Trail Ranches, [consolidated] and the damages to the ranches from the construction and operation of the new power line.

- Testified as an EMF and corona noise expert in the Colorado Public Utility Commission hearings on the Xcel Energy Midway to Daniels Park transmission line.

- Testifying as an EMF and corona noise expert in the Colorado PUC hearings on the San Luis Valley to Calumet to Comanche transmission line project in Southern Colorado and several transmission line projects in Eastern Colorado.

- Participated as an expert in the Xcel Energy hearings for the Silverthorne Substation in central Colorado, the Chambers Transmission Line rebuild project in Aurora Colorado and the Brantner/Thornton Substation in Adams County, Colorado.

EMF Publications

Pearson, R.L., and H. Wachtel. An Examination of the Residential and Lifestyle Factors Which May Underlie the Wire Code Paradox. RP2964-22, Electric Power Research Institute, January, 1994.

Pearson, R.L., and H Wachtel. "An Examination of the Residential and Lifestyle Factors Which May Underlie the Wire Code Paradox." Presented at The Annual Review of Research on Biological Effects of Electric and Magnetic Fields From the Generation, Delivery and Use of Electricity, Savannah, Georgia, November, 1993.

Wachtel, H., and R.L. Pearson. "An Approach to Unraveling the Wire Code Paradox." Presented at The Annual Review of Research on Biological Effects of Electric and Magnetic Fields From the Generation, Delivery and Use of Electricity, Savannah, Georgia, November, 1993.

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Wachtel, H., R.L. Pearson and K.L. Ebi, Could Air Pollution Be a n Alternative to or a Cofactor With Magnetic Fields as a Link Between Wire Codes and Childhood Cancer? Presented to the Annual Meeting of the Bioelectromagnetics Society, Boston Massachusetts, June 1995.

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Wachtel, H., R.L. Pearson and K.L. Ebi. Childhood cancer Risk in Relation to Wire Code Associated REL factors and Causal Links that are Implicated. Presented at The Annual Review of Research on Biological Effects of Electric and Magnetic Fields From the Generation, Delivery and Use of Electricity, Palm Springs, California, November, 1995.

Pearson, R.L., H. Wachtel and K.L. Ebi. Assessing Possible Control Selection Bias Using a Method for Automatic Wire Coding. Presented to the Annual Meeting of the Bioelectromagnetics Society, Victoria, B.C. Canada, June, 1996.

Wachtel, H., R.L. Pearson and K.L. Ebi. Rental Status and Wire Code Are Risk Factors for Childhood Cancer. Presented to the Annual Meeting of the Bioelectromagnetics Society, Victoria, B.C. Canada, June, 1996.

Pearson, R.L. "Transmission Lines, Electric and Magnetic Fields." Encyclopedia of Chemical Processing and Design, Volume 47, Marcel Decker, Inc., New York, July, 1996

Wachtel, H., R.L. Pearson and K.L. Ebi Distance Weighted Traffic Density Is Associated With Wire Code And Is A Risk Factor For Childhood Cancer. Presented at The Annual Review of Research on Biological Effects of Electric and Magnetic Fields From the Generation, Delivery and Use of Electricity, San Antonio, Texas, November, 1996.

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Zaffanella, L.E., S. Greenland, D.A. Savitz, R.L. Pearson, and R. Iryie. Application of the Case Specular Method to the Savitz Denver Study Residences. Technical Report 107751, Electric Power Research Institute, Palo Alto, California, 1997

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Pearson, R.L., H. Wachtel, K.L. Ebi. The Use of Automatic Wire Coding to Evaluate Control Selection Bias in the Savitz et. al. Study. Technical Report TR-108044, Electric Power Research Institute, Palo Alto, California, August, 1998.

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Wachtel, H., R.L. Pearson and K.L. Ebi. Traffic Density And Wire Codes May Be Risk Cofactors For Childhood Cancer. Presented to the Annual Meeting of the Bioelectromagnetics Society, Long Beach California, June, 1999.

Pearson, R.L., H. Wachtel, K.L. Ebi and J Crawford. Wire Codes And Traffic Density Are Associated On A Citywide Basis. Presented to the Annual Meeting of the Bioelectromagnetics Society, Long Beach California, June 1999.

K. L. Ebi , L. Kheifets, R. L. Pearson and H. Wachtel. Evaluation of Control Selection Bias in the Savitz et al. Childhood Cancer Study, 2000. Journal of the Bioelectromagnetics Society, vol 21, pp 346-53.

Pearson, R.L., H. Wachtel and K.L. Ebi. Distance Weighted Traffic Density in Proximity to a Home is a Risk factor for Childhood Cancer, Particularly Childhood Leukemia, 2000. Journal of the Air and Waste Management Association, vol. 50, pp175-80.

Pearson, R.L., H. Wachtel and K.L. Ebi. Traffic Density as a Risk Factor for Childhood Cancer in Denver and Los Angeles. Technical Report TR-114231. Electric Power Research Institute, Palo Alto, California, December 1999.

R. Pearson, H. Wachtel, K. Ebi, J. Crawford, Association Of Traffic Density With Wire Codes, Comparison Of Patterns Seen In Los Angeles And Denver. Presented to the Annual Meeting of the Bioelectromagnetics Society, Munich, Germany, June 2000.

H. Wachtel and R. Pearson. Interactions of traffic density and wire codes as cancer risk factors—a comparison of results in Los Angeles with those in Denver. Presented to the Annual Meeting of the Bioelectromagnetics Society, Munich, Germany, June 2000.

R.L. Pearson, H.Wachtel, and K.L. Ebi. Integrated Distance Weighted Traffic Density In Proximity To A Home Is A Risk Factor For Leukemia And Other Childhood Cancers. Presented to the Annual meeting of the Air and Waste Management Association, Salt Lake City Utah, June 2000.

H. Wachtel and R. Pearson. Combined Exposures to High Levels of Air Pollution and Electromagnetic Fields May Increase Leukemia and Other Cancer Risks in Children.

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