ECC Statement No. 2
Witness: Dr: Robert Q. Hanham

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BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

In re: Application of Trans-Allegheny Interstate Line Company	:	Docket Nos. A-110172, A_ 110172F0002-F0004 and G-00071229

DIRECT TESTIMONY OF DR. ROBERT Q. HANHAM

October 31, 2007

Q. STATE YOUR NAME AND ADDRESS.

A. My name is Robert Q. Hanham and my work address is Department of Geology and Geography, Box 6300, West Virginia University, Morgantown, WV 26506.

EMPLOYMENT

Q. WHAT IS YOUR CURRENT OCCUPATION?

A. I am an Associate Professor of Geography at West Virginia University.

EDUCATION AND EXPERIENCE

Q. DESCRIBE YOUR EDUCATIONAL EXPERIENCE.

A. I was awarded a Bachelor of Arts Degree (Geography) from Reading University (United Kingdom) in 1969, a Masters in Geography from The Ohio State University in 1971, and a Ph.D. in Geography from The Ohio State University in 1973.

Q. DESCRIBE YOUR PROFESSIONAL EXPERIENCE.

A. From 1973 until 1981, I was a faculty member of the Department of Geography at the University of Oklahoma. Since 1981, I have been a faculty member of the Department of Geography at West Virginia University. My primary research and teaching specialty has been uneven economic development. The theory of uneven economic development touches on many issues, including environmental and health aspects. I have been awarded numerous grants and published many peer-reviewed articles on all aspects of uneven economic development.

Since 1974, I have taught a graduate level course in advanced geo-statistics, *i.e.* the use of statistical methods in various fields and applications, including epidemiology. Since the early 1990s, I have taught a semester-long course each year on climate change, addressing global warming, pollution, ozone depletion, and acid rain.

I have conducted research with various epidemiologists and community health specialists at West Virginia University. For example, pursuant to research grants from the Centers for Disease Control and Prevention, I, along with a community health specialist, researched obesity and health in the Appalachian region for approximately two years

(from 2002 through 2004). For a fuller discussion of my qualifications, see my curriculum vitae attached as Exhibit RQH-1.

Q. HAVE YOU HAD EXPERIENCE REVIEWING RESEARCH OF OTHERS IN THE FIELD OF UNEVEN ECONOMIC DEVELOPMENT?

A. Yes. The process of reviewing and critiquing the scientific work of others is an essential part of my job and it has broad application in academia. During my career, I have had countless opportunities to review and critique research proposals and articles in uneven economic development and related fields. For example, I have had 17 doctorate students and dozens of masters students in the area of uneven economic development. I also have reviewed countless articles and research grant proposals related to uneven economic development.

PURPOSE OF TESTIMONY

Q. DESCRIBE THE PURPOSE OF YOUR TESTIMONY.

A. I have been asked by the Energy Conservation Council of Pennsylvania to evaluate the impact of the powerlines proposed by the Trans-Allegheny Interstate Line Company ("TrAILCo") based on my expertise in uneven economic development, including pollution and health effects.

My testimony focuses on the uneven economic development between Greene and Washington counties, the proposed site of the powerlines, and Loudon County, Virginia, the beneficiary of the proposed powerlines. I conclude that the proposed powerlines will increase the value of the eastern communities, at the expense of Greene and Washington counties, which will be devalued by the powerlines. I base this conclusion on the fact that Greene and Washington counties will suffer substantially greater pollution from the increased power generation, greater health risks as a result of both the pollution and the proximity of the powerlines, and lower property values.

My opinions include an academic critique of the work of Dr. Bailey who TrAILCo hired for the purpose of discounting the health risks associated with electric and

magnetic fields (EMFs) generated by high power transmission lines. Uneven economic development is, above all, concerned with social, economic, and environmental justice.

UNEVEN ECONOMIC DEVELOPMENT

Q: WHAT IS UNEVEN ECONOMIC DEVELOPMENT?

A: *Uneven development is a geographical theory that explains why economic development* in the world is so unbalanced. The theory argues that, in a profit-driven economic system, the economic development of one place always goes hand-in-hand with the devaluation of another place. In fact, one requires the other. The value of one or more places is reduced so that the value of the developed place can be raised.

The theory is used to explain the huge disparities in status of development whether on a macro sale, (*i.e.* comparing economics in the global economy) or a micro *scale (i.e. comparing sections of a city).*

Q: HOW DOES THE THEORY OF UNEVEN ECONOMIC DEVELOPMENT APPLY TO THE POWERLINES PROPOSED BY TRAILCO?

A: The powerlines proposal by TrAILCo is a classic example of the theory in action. The value of communities in Greene and Washington counties are going to be reduced so that the value of communities on the east coast can be raised. Businesses, households, individuals, and even local governments in Greene and Washington counties will be *devalued due to the powerlines proposed by TrAILCo.*

Q. PLEASE COMPARE THE BASIC POPULATION DEMOGRAPHICS OF WASHINGTON AND GREENE COUNTIES, PENNSYLVANIA TO LOUDOUN COUNTY, VIRGINIA.

A. According to data published on the U.S. Census Bureau website, the estimated population of Washington County and Greene Counties, as of July 1, 2006, totals approximately 247,000. Source Annual Estimates of the Population for Counties of Pennsylvania: April 1, 2000 to July 1, 2006 http://factfinder.census.gov/home/saff/main.html?_lang=en (see Exhibit RQH-2). The estimate for Loudoun County, part of the greater Washington D.C.

metropolitan area, is 268,817. Source Annual Estimates of the Population for Counties of Virginia: April 1, 2000 to July 1, 2006 (see Exhibit RQH-3). http://factfinder.census.gov/home/saff/main.html?_lang=en. From 2000 to 2006, Loudoun's population has increased by an estimated 95,000. By contrast, over the six year span, the combined estimate population growth in Washington and Green Counties total 3,200. *Compare* Exhibit RQH-2 *with* Exhibit RQH-3. Actually, the U.S. Census Bureau estimate a slight decline in the population of Greene County. Exhibit RQH-2.

The U.S. Census Bureau's estimates show Loudoun County has experienced rapid growth since 2000. By contrast, Washington County has experienced modest growth and Greene County has remain static or slightly declined.

Q. IN THE CONTEXT OF TRAILCO'S APPLICATION, WHAT CONCLUSIONS MAY BE DRAWN FROM THESE BASIC DEMOGRAPHIC DATA?

A. The influx of over a third of Loudoun County's population within the past six years has caused increased electrical consumption. As the Pennsylvania Chapter of the Sierra Club notes and TrAILCo admits in its West Virginia application, four (4) new generation plants may be built to service the proposed powerlines which terminate in the east in Loudoun County. Source Testimony & Comments of the Pennsylvania Chapter of the Sierra Club (see Exhibit RQH-4). Even TrAILCo's own witnesses acknowledge that the economic potential in the electrical consumption outside of Southwestern Pennsylvania drives TrAILCo's proposal and the alleged need for the proposed powerlines.

Loudoun's staggering growth, the terminus of the proposed powerlines in Loudoun County, and TrAILCo's admission of increased electrical generation -- all viewed further in the context of the minimal combined growth of Washington and Greene Counties -- leads to the conclusion that TrAILCo ultimately plans to benefit Loudoun County by transferring increased electrical generation over the proposed powerlines.

Q. WHAT IS THE MEDIAN HOUSEHOLD INCOME OF THE COUNTIES?

A. According to data from the U.S. Census Bureau the median household income for Loudoun County in 2006 was estimated at $99,371. Source: U.S. Census Bureau

Loudoun County, Virginia Selected Economic Characteristics: 2006 (see Exhibit RQH-5). By contrast, Washington County's median household income was $45,789. Source: U.S. Census Bureau Washington County, Pennsylvania Selected Economic Characteristics: 2006 (see Exhibit RQH-6). Data for 2006 was unavailable for Greene County; however, in 2000, the median household income was $30,352. Source: U.S. Census Bureau Greene County, Pennsylvania Profile of Selected Economic Characteristics: 2000 (see Exhibit RQH-7).

Q. WILL COSTS ASSOCIATED WITH THE POWERLINES BE DISPROPORTIONATELY ABSORBED IN WASHINGTON AND GREENE COUNTIES?

A. Yes. Costs associated with the powerlines will be disproportionately absorbed by Greene and Washington Counties, while Loudoun County receives the benefit of increased electrical generation. For example, a TrAILCo witness testified the estimated costs associated with the powerlines will be paid by TrAILCo's customers and other load serving entities in PJM. Source: TrAILCo Supplemental Direct Testimony of Mark A. Mader. Costs will be unduly absorbed by customers in Washington and Greene Counties, who on average have less means than their counterparts in Loudoun County and who do not benefit from the transferred electricity. Source: Energy Conversation Council of Pennsylvania Statement No. 1 regarding the failure of TrAILCo to prove a need for the proposed project in Pennsylvania.

The powerlines do not increase the property values of affected customers. TrAILCo's conduct of paying customers "damages" and seeking "Damages Release" acknowledges that fact. Construction of the powerlines will lead to devaluation of the property upon which they sit, causing a potential drop in tax revenue.

Additionally, the increased coal-fired electric generation will produce more environmental pollution and increased health risks. Greene and Washington Counties will host the lines, and, along with other parts of Pennsylvania, are in closer proximity to

the generation sources. Thus, they will be disproportionately impacted by pollution and increased health risks.

Customers face direct costs, pollution, and increased health risks. Local governments face potentially declining revenues while simultaneously confronting potentially vast new costs posed by health care and environmental risks associated with coal-fired generation.

TrAILCo's application fails to address or evaluate the impacts of uneven economic development, including the potential costs and dangers to Pennsylvania and its residents resulting from the disproportionate pollution, adverse health effects, etc., on Washington and Greene Counties, or any other part of Pennsylvania.

UNEVEN ECONOMIC DEVELOPMENT AND POLLUTION

Q: DOES POLLUTION CONTRIBUTE TO UNEVEN ECONOMIC DEVELOPMENT?

A: Yes. Increased pollution from the proposed powerlines will contribute substantially to the devaluation of Pennsylvania, including Greene and Washington counties. Expanded transmission capacity typically requires greater power generation, which in turn requires the increased burning of fossil fuels and thus more harmful and toxic waste through increased atmospheric emissions and additional waste in area landfills (the ash).

Globally, fossil fuel power plants are a major contributor to global warming. The causes of global warming are carbon dioxide emissions (47%), black carbon particulates (16%), methane (14%), ozone (12%), CFCs (7%) and nitrogen oxides (4%). Fossil fuel power plants emit all of these pollutants, except for CFCs. Typically, a 1000 megawatt (MW) coal-fired power plant in the United States emits on average 5.6 million tons of CO_2 per year. TrAILCo's proposal will likely increase the generational output of existing plants and/or lead to the construction of additional coal-fired generating plants, with a corresponding increase in CO_2 output. While global warming is and will continue to affect communities in Greene and Washington counties (and communities worldwide), global warming's impact will be uneven, and increased power generation could worsen

the local impact. Source: Intergovernmental Panel on Climate Change (IPCC) (2007) (see Exhibit RQH-8).

Fossil fuel power plants also cause huge quantities of toxic waste to be emitted into the air and dumped in landfills in Greene and Washington counties. Even at current levels, the health and environmental effects of this toxic waste are as follows: (sources: health information from Centers for Disease Control and Prevention and chemical information from EPA's Toxic Release Inventory (2005) (see Exhibit RQH-9).

•Hydrochloric acid (2553 tons into the air a year from both counties) and sulfuric acid (567 tons a year into the air) both cause respiratory disease. They also are the leading causes of acid rain in this country.

•Lead (almost one ton emitted into the air and 8 tons buried in landfills a year), mercury (a quarter of a ton into the air a year) and dioxin are all neurotoxins, and dioxin is also a carcinogen.

•Chromium (almost one ton into the air and 18 tons in landfills) can cause lung cancer.

•Nickel (half a ton into the air and 16 tons in landfills) is a carcinogenic in large quantities.

•Barium (3 tons into the air and 100 tons in landfills) can cause kidney damage.

•Zinc (2 tons into the air and 21 tons in landfills) is known to cause infertility in animals.

•Vanadium (more than one ton into the air and 35 tons in landfills) is known to cause birth defects in animals.

•Arsenic (almost one ton into the air and 8 tons in landfills) is highly poisonous.

Exposure to air pollution in Pennsylvania is especially acute. Sources: Exhibit RQH-4; Comments of Sierra Club, Pennsylvania Chapter, Clean Air Committee (see Exhibit RQH-10). Ozone, smog, and particulate matter, 2.5 microns and smaller (PM 2.5), in Southwestern Pennsylvania is particular acute. *Id.* Such pollution is potentially respirable and causes a variety of potentially life-threatening illness. *Id.*

Increased power generation leads only to increased toxic pollution whether emitted into the air or dumped into the landfills, including landfills in Greene and

Washington counties. The situation in Pennsylvania, already detrimentally impacted by existing pollution, will be exacerbated by increased electric generation.

Q. WHAT IS LOUDOUN COUNTY'S BURDEN WITH RESPECT TO THE INCREASED ELECTRICAL GENERATION?

A. By comparison, Loudon County, which has a population only slightly greater than that of Greene and Washington Counties combined (approximately 268,000 for the former and 247,000 for the latter two), is not directly or proportionately burdened by production of such wastes. In fact, Loudon County does not apparently have any local utility plants. Source: EPA's Toxic Release Inventory (2005) (see Exhibit RQH-9). Loudon County is also not subject to the same burden as Southwestern Pennsylvania which is closer to generational sources in the Ohio River Valley.

Q. DOES INCREASING POLLUTION LEAD TO FURTHER UNEVEN ECONOMIC DEVELOPMENT?

A. Yes. Ultimately, Greene and Washington counties are already disproportionately impacted by toxic waste from utilities. The Counties should not be further burdened, particularly when Loudon County, which will benefit from the proposed powerlines, is not exposed to this extensive amount of waste or pollution.

UNEVEN ECONOMIC DEVELOPMENT AND ADVERSE HEALTH RISKS

Q: HAVE YOU REVIEWED TRAILCO'S STATEMENT REGARDING THE PROPOSED POWERLINES' EFFECTS ON HUMAN HEALTH?

A. Yes, I had the opportunity to review TrAILCo's Statement No. 8 before the PUC.

Q: WHAT IS YOUR VIEW OF THAT STATEMENT?

A. There are numerous problems with the reasoning and methodology employed by Exponent, Inc., the for-profit consulting firm hired by TrAILCo to prepare and provide the health-related research on EMFs.

Q. WHAT TYPES OF PROBLEMS?

A. First, the author of TrAILCo's Statement No. 8, entitled Current Status of Health-Related Research Of Electric and Magnetic Fields, is William Bailey Ph.D. Significantly, Dr.

Bailey is not an epidemiologist, but rather specializes in neuropsychology (the study of psychiatric and neurological disorders).

Second, Dr. Bailey includes many unsupported assertions in his report. For example, he emphatically states that the proposed powerlines will not contribute significantly to the exposure of the public in Pennsylvania (page 7, lines 1-3). He bases this conclusion on the following assertions:

"The proposed route is situated mainly in rural areas at a distance from *most residences*' (page 7, lines 6-7).

"Exposures to fields from the proposed line would be of limited duration and intermittent, such as those experienced by persons hiking on trails or crossing the right-of-way" (page 7, lines 7-9).

"Riders in vehicles passing under the line would be largely shielded from exposures to the electric field" (page 7, lines 9-10).

"The electric fields associated with the new line would contribute little to *exposures at residences because of distance from the line and the* effective blocking of these fields by trees, fences, shrubbery and buildings" (page 7, lines 11-13)

"[TrAILCo has a] strategy of attempting to avoid routing TrAIL near residences" (page 8, line 22).

Dr. Bailey ignores the fact that many residences are located very near the proposed transmission line and that many residents will be forced to live, play, or work *next to or under the line. No support or evidence exists for Dr. Bailey's claims* that cars or nearby trees, fences, shrubbery or buildings can or will effectively shield residents from exposures.

Third, Dr. Bailey, in assessing the potential health effects of exposure to EMFs, concludes that "[t]he scientific consensus among these agencies is that the evidence is insufficient to conclude that EMF is a cause of any long-term health effect." In reaching this conclusion, Dr. Bailey claims to rely on the weight-of-evidence research of the

International Agency for Research in Cancer (IARC) and the National Institutes of Environmental Health Sciences (NIEHS). There are several problems, however, with Dr. Bailey's conclusions based on this research.

Q. EXPLAIN SOME OF THE PROBLEMS WITH DR. BAILEY'S CONCLUSIONS.

A. NIEHS did in fact classify EMFs as a "possible carcinogen" with respect to childhood leukemia (see California EMF Program review, page 27). With respect to IARC, Dr. Bailey, himself, states: "Overall, magnetic fields were categorized [by IARC, of which Dr. Bailey was a member] as possibly carcinogenic to humans...based on the statistical association of higher magnetic fields with childhood leukemia." (page 14, lines 14-16).

Other individuals, authorities, and agencies, including the California Department of Health Services (CDHS), have reached different conclusions than those of the studies relied on by Dr. Bailey.[1] Source: CDHS: An Evaluation of the Possible Risks from Electric and Magnetic Fields (EMFs) from Power Lines, Internal Wiring, Electrical Occupations, and Appliances (June 2002) (Exhibit RQH11). The CDHS, in an extensive four hundred page review of EMF health impact undertaken for the California PUC and published in 2002, evaluated the biophysical, mechanistic, animal pathology and epidemiological research on the subject (see pages 9-10 and pages 18-23 in the CDHS review for a discussion of these four types of evidence). The CDHS concluded that (see pages 24-26 in CDHS):

- One or more of the reviewers strongly believe that EMFs increase the risk of childhood leukemia
- One or more of the reviewers were prone to believe that EMFs increase the risk of adult leukemia and adult brain cancer
- One or more of the reviewers were close to the dividing line between believing or not that EMFs increase the risk of childhood

[1] Testimony at the public input hearings identified several other epidemiological studies that show potential adverse health effects from EMFs. TrAILCo and Dr. Bailey appear to reject this evidence as well.

brain cancer, breast cancer, miscarriage, Lou Gehrig's disease, Alzheimer's, heart disease and suicide.

Q. IS DR. BAILEY'S CRITICISM OF THE CDHS REPORT BALANCED AND OBJECTIVE?

A. No. Dr. Bailey's criticisms of CDHS report are wholly unpersuasive. First, Dr. Bailey states that "The review...lacked the multidisciplinary expertise of the other national and international [studies], specifically with regard to biological sciences" (pages 16-17, lines 22-1). This is simply incorrect; the California study (page 7, lines 10-20 in CDHS) states quite clearly that specialists in biophysics, statistics, animal experimentation and toxicology were employed to assist the epidemiologists who did the review.

Dr. Bailey's second criticism of the CDHS study is that 'The review...did not adequately consider animal studies or other types of laboratory studies' (pages 16-17, lines 22-3). This criticism highlights a larger problem with Dr. Bailey's statement. Dr. Bailey repeatedly downplays the epidemiological evidence, which does tend to support an association between EMFs and adverse health effects (see page 17, lines 9-16 and page 18, lines 18-23). Dr. Bailey's entire testimony erroneously assumes that evidence of a causal link between EMFs and adverse health can only come from animal studies, not epidemiological ones. From my experience, this is typical of a strategy that is widely used by industry to discredit studies that show a statistical association between a causal factor and adverse health.

Q. IS THERE A PROBLEM WITH RELYING ON ANIMAL EXPERIMENTS?

A. Yes. Animal experiments often say nothing meaningful about the connection between a causal factor and adverse health. Many human drugs that have been withdrawn over the past few years were determined to be safe because their initial testing relied on animal experiments that did not relate to human conditions. For example, Merck was able to put the pain-killer Vioxx on the market because animal studies seemed to show that it was safe. Subsequent clinical trials showed it caused cardiac risk to humans. The company

was successfully sued, specifically for relying on animal tests. There are many other such examples.

Q. DID THE CDHS REPORT WEIGH DATA FROM ANIMAL EXPERIMENTS?

A. Yes. The CDHS report considered animal studies in its review, but on equal terms with other forms of evidence, not preferentially. The report gives three reasons why animal experiments of the EMF mixture might miss the true effect of EMFs on health (page 19). First is the problem of finding the right animal, one that mimics the human anatomy. Second is the problem of finding the right mixture of EMFs effect to relate to animal response. Third is the questionable assumption in animal pathology studies of a monotonically increasing risk between cause (EMFs) and effect (adverse health), when many epidemiological studies indicate a more complex relation that is not necessarily monotonic (*i.e.*, it jumps around, up and down, not a steady increase in other words).

Q. DO YOU BELIEVE THE SCIENTIFIC APPROACH EMPLOYED BY CDHS TO BE MORE RELIABLE TO ASSESSING THE HEALTH RISK POSED BY EMF THAN THE IARC AND NIEHS STUDIES?

A. Yes. In addition to the items I have already discussed, the CDHS report further explains why its findings tend to identify a stronger connection between EMF and adverse health than the IARC and NIEHS studies.[2] First, the CDHS reviewers used a far more detailed rating scheme than IARC. CHDS reviewers used probabilities (a ratio scale) to assess the confidence they had in each research study. IARC reviewers used a simple binary response (yes or no) in evaluating studies. Second, the CDHS report incorporated the assessments of all their reviewers, positive or negative. The IARC report, on the other hand, simply gave the majority opinion. Although a sizable minority of the IARC reviewers believed there to be some indication of a link between EMF and adverse health in animal studies, this fact was not incorporated into the IARC findings (see CDHS, page

[2] Interestingly, the CDHS reviewers participated in the NIEHS study and one of the reviewers participated in the IARC study, presumably alongside William Bailey. Accordingly, the CDHS reviewers were aware of the what had occurred in these previous studies.

28-29, lines 77-13). This skewed the interpretation in IARC to suggest no link between EMF and health. Third, the CDHS reviewers met regularly over a period of 'innumerable hours and days over a period of years' (CDHS page 28, lines 64-68) to discuss their findings before creating a draft report. The IARC report was drafted over five days, only ten percent of which was devoted to discussion (CDHS, page 57-64). Similarly, "the NIEHS evaluation [where] the decision was reached [occurred] over a ...week-long meeting, followed by a vote." (CDHS page 29, lines 14-16).

Q. WHAT ARE YOUR CONCLUSIONS ABOUT DR. BAILEY'S WORK?

A. There are numerous problems with the statement of Dr. Bailey. Primarily, he erroneously focuses solely on animal studies to the exclusion of epidemiological studies. By using this approach, he unjustly diminishes the CDHS study, which shows an extensive and significant link between EMF and health issues. In fact, Dr. Bailey applies only unbalanced and subjective criticism to reject the CDHS report. Dr. Bailey's work is ultimately not well-reasoned.

CONCLUSIONS

Q. DOES TRAILCO'S PROPOSAL LEAD TO UNEVEN ECONOMIC DEVELOPMENT?

A. Yes. The scenario before the Commission is classic uneven economic development. The driving purpose of TrAILCo's proposal is to exploit an economic opportunity it has identified in the developing urban areas of Loudoun County. As demonstrated, rural Washington County and Greene County will directly absorb costs of hosting the powerlines, including paying for their existence as well as sustaining loss of property value, without receipt of a benefit. Those counties and Pennsylvania, as a whole, will unduly absorb costs of the increased electric generation. These costs include increased pollution and health risks. Because TrAILCo does not address the impact of most of these costs on Washington or Greene Counties or Pennsylvania as a whole, its application should be denied.

TrAILCo does attempt to offer the report/testimony of Dr. Bailey for the proposition that EMFs do not pose demonstrable health risks for humans. However, Dr.

Bailey's selective analysis is fundamentally unreliable. There is credible, vetted epidemiological evidence which reaches opposite conclusions.

Ultimately, TrAILCo's proposal leads to uneven economic development which is not socially, economically, or environmentally just.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

ROBERT Q. HANHAM

Curriculum Vitae
(excludes conference presentations)
October, 2007

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EDUCATION

Ph.D. Geography, Ohio State University 1973
M.A. Geography, Ohio State University 1971
B.A. Geography, Reading University (UK) 1969

PROFESSIONAL EMPLOYMENT

1981-present, Associate Professor of Geography, Department of Geology and Geography, WVU

1987-1992, Geography Program Director and Assistant Chair, Department of Geology and Geography, WVU

1996-1999, Geography Graduate Studies Coordinator, Dept. of Geology and Geography, WVU

1981-1992, Geography Graduate Studies Coordinator, Dept. of Geology and Geography, WVU

1981-1987, Research Associate Professor, Regional Research Institute, WVU

1980-1981, Senior Lecturer, Department of Geography, Portsmouth Polytechnic, England

1979-1980, Associate Professor, Department of Geography, University of Oklahoma

1973-1980, Graduate Studies Coordinator, Department of Geography, University of Oklahoma

1973-1979, Assistant Professor, Department of Geography, University of Oklahoma

RESEARCH GRANTS AND AWARDS

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Joel Halverson and Robert Hanham, 2002-03, "Obesity in Appalachia: an Atlas of Geographic Disparities," Federal Centers for Disease Control and Prevention, Atlanta, $254,804.

Joel Halverson and Robert Hanham, 2001-02, "Economic Change and Local Community Mental Health: Social Dimensions of Suicide in Appalachia," Federal Centers for Disease Control and Prevention, Atlanta, $29,161.

Robert Hanham, "Exploring the Use of Local Network Autocorrelation Statistics in the Analysis of Inter-industry Linkages in West Virginia," 8/99 to 7/00, Bridge Grant, Regional Research Institute, West Virginia University.

Robert Hanham, "Regional Manufacturing Employment Change: a Spatial Analysis of Growing and Lagging Local Areas in Japan," 8/97 to 7/00, Faculty Research Associate Award, Regional Research Institute, West Virginia University.

Robert Hanham, "Spatial Models of Unemployment in the U.S. Metropolitan System," 3/86 to 2/88, $44,000, National Science Foundation, Geography and Regional Science Program.

F. Calzonetti, M. Choudhry, R. Duval, G. Elmes, R. Hanham, P. Mann, T. Torries and T. Witt, "An Integrated Assessment of Electricity Export from West Virginia," 7/84 to 6/86, $225,000, Energy Research Center, West Virginia University.

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Robert Hanham, Junior Faculty Summer Fellowship, University of Oklahoma, 1974.

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Robert Hanham and Hong-Yih Chang, 1981, "Wage Inflation in a Growth Region: The American Sun Belt," in R. Martin (ed.) Regional Wage Inflation and Unemployment (Pion).

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Robert Hanham and Edward Malecki, 1979, "Rural Diffusion Research, Area, 11, 129-130.

Robert Hanham, 1979, "Spatial Diffusion and the Use of Multidimensional Scaling in Scriation Problems," Area, 11, 179-184.

Robert Hanham and Hong-Yih Chang, 1979, "Scalar Variation and Nodal Accessibility in the Chinese Railroad Network," Professional Geographer, 31, 388-392.

Robert Hanham and Hong-Yih Chang, 1979, "Urban Accessibility and the Railroad Network of China," Geographical Research, 5, 183-188.

Robert Hanham, 1978, "Comments on the Wildness Continuum," Professional Geographer, 30, 415.

Lawrence Watson and Robert Hanham, 1977, "Flower Color and Environment: The Case of Butterflyweed in Oklahoma" Professional Geographer, 29, 374-377.

William Turner, Robert Hanham and Anthony Portararo, 1977. "Population Pressure and Agricultural Intensity," Annals of the Association of American Geographers, 67, 384-396.

Robert Hanham and Lawrence Brown, 1976, "Diffusion Waves Within the Context of Regional Economic Development" Journal of Regional Science, 16, 65-71.

Robert Hanham, 1976, "Factorial Ecology in Space and Time; An Alternative Method," Environment and Planning A, 8, 823-828.

Lawrence Watson and Robert Hanham, 1976, "Environment and the Morphological Characteristics of Butterflyweed in Oklahoma," Journal of Biogeography, 3, 383-388.

Robert Hanham and Lawrence Brown, 1972, "Diffusion Through An Urban Hierarchy: The Testing of Related Hypotheses," Tijdschrift Voor Economische en Sociale Geografie, 63, 388-392.

COURSES CURRENTLY TAUGHT

Geog 207: Climate and Environment. An undergraduate course on the geography of climate change. Topics include global warming, atmospheric pollution, acid rain, ozone depletion and local and regional climate change.

Geog 209: Economic Geography. An undergraduate course on the geography of economic systems and economic development. Topics include uneven development, Kondratieff cycles of development, global core-periphery relations, globalization, the geography of food in/sufficiency and the geography of resource conflicts.

Geog 601: Geographic Traditions. A required graduate course on the different philosophies of knowledge production in the academic discipline of Geography.

Geog 701: Advanced Research Methods. A required graduate course on advanced quantitative research methods and advanced geostatistical methods.

Geog 711: Regional Development. A graduate course on the theory of uneven development, imperialism, the politics of scale and the production of place.

GRADUATE STUDENTS

Current PhD Students

Jacquelyn Core, The state and uneven development.
Janice Hardin, The politics of scale and uneven development.
Chris Schaney, Environment and the production of urban place.
Denyse Wyskup, Uneven development, place and Native American identity.

Current MA Students

Bobbie Alt, Geography of obesity in Appalachia.
Patrick Ehland, Uneven development in Central Asia.
Michael Mandeville, Local economic development in southern West Virginia.

Former PhD Students

Richard Hoch, 2005, *An analysis of fragmented land-use policy and land-use change: the case study of metropolitan Pittsburgh* (Assistant Professor, Indiana University, Pennsylvania).

Joel Halverson, 2005, *Suicide and socioeconomic context in the Appalachian region* (Assistant Research Professor, Department of Community Medicine, West Virginia University).

Scott Spiker, 2004, *Using spatial statistics to model the spatial structure of data in remote sensing change detection: the case of urban sprawl* (Assistant Professor, University of Wisconsin-Parkside).

Eric Spears, 2004, *Politics of space and scale in the Brazilian favela: a case study of São Pedro* (Director of International Programs, Mercer University, Georgia).

Shawn Banasick, 2001, *Beyond the workplace: the uneven development of the Japanese space-economy and the role of labor, 1965-1994* (Assistant Professor, Kent State University, Ohio).

Jay Gatrell, 1999, *Localized innovation: a geography of the petro-chemical industry in the Kanawha Valley of West Virginia* (Associate Professor, Indiana State University, Indiana).

Hong-Yih Chang, 1983 (OU), *Spatial aspects of wage inflation in the urban system of the US.*

Dennis Hrebec, 1983 (OU), *A distance-based analysis of urban segregation in the American SW.*

Harold Elliott, 1979 (OU), *The structure and evolution of the geographic system.*

Don Greene, 1979 (OU), *The American Agriculture Movement: its cause, spread and impact.*

Ramadan Khalfallah, 1979 (OU), *Migration, labor supply and regional development in Libya.*

Larry Watson, 1975 (OU), *The geographic variation of Asclepias tuberosa interior in Oklahoma.*

Former MA Students (at WVU)

Janice Hardin, 2003, *Rescaling the Innu.*

Miho Soda, 2003, *Using remote sensing to detect forest change associated with timber processing mills in West Virginia.*

Josh Kincaid, 2001, *Spatial models of forest-environment relationships on the Appalachian Plateaus: the Allegheny Mountain section, western Maryland.*

Richard Hoch, 1999, *Uneven development of nature: an historical geography of Ohiopyle State Park.*

Ben Morton, 1999, *Productivity and economic growth in the Pittsburgh region from 1850 to 1900.*

Harry Nichols, 1999, *An applied market area study of the Harley-Davidson Motor Company in the New York City region.*

Scott Sizer, 1999, *Locating and mapping cemeteries in Loudon County, Virginia.*

Li-Ting Hung, 1998, *"They don't throw, they turn; they don't fire, they burn": place and identity in Seagrove, NC.*

Stuart Lorkin, 1998, *The de/re-territorialization of struggle in Appalachia: the legacy of 'coal and class' and the cultural politics of community.*

Valerie Braham, 1997, *Cancer and toxic air emissions in the Kanawha Valley.*

Vernon Deal, 1996, *The Cranberry Backcountry: scale, ecosystem dependence and the conflict between the production and consumption of nature.*

Shawn Banasick, 1995, *Crisis and the uneven development of the Japanese space-economy.*

Joel Shelton, 1995, *Scale and uneven development in the industrial Midwest.*

Carol Woody, 1995, *Manufacturing jobs and restructuring in West Virginia, 1954-1985.*

William Gale, 1994, *Conceptualizing space, scale and everyday life in a new regional geography.*

Raymond Kurtiak, 1994 (co-chair Dr Weiner), *Urban restructuring and socio-economic polarization: an analysis of income levels in Pittsburgh, PA, 1950-1990.*

Scott Spiker, 1992, *A geographical analysis of unemployment in the United States, 1965-1985.*

Todd Nesbitt, 1991, *Crisis and restructuring in the US steel industry: a geographical analysis, 1967-1987.*

Michael Lorenz, 1990, *Geographical variations in community response to Baltimore's central light rail transit project.*

John Grande, 1988, *Impact of the geographic concentration of the elderly on voting in West Virginia.*

Andrew Herod, 1988, *Industrial reorganization and the local response to plant closures: a new politics of manufacturing decline.*

William Mallet, 1988, *The social production of urban space: a case study of Pittsburgh's Hill District, 1945-1970.*

Tim Allison, 1987, *The impact of changing energy prices on state tax revenues, 1965-1985.*

Jeffrey Jollie, 1985, *Analysis of monitoring well siting procedures at solid waste disposal facilities in Maryland.*

Nicholas Buss, 1983, *Energy trade balances and state economic development.*

ECC Exhibit RQH-2

Pennsylvania -- County
GCT-T1. Population Estimates
Data Set: **2006 Population Estimates**

Note: For information on errors stemming from model error, sampling error, and nonsampling error, see: http://www.census.gov/popest/topics/methodology.

	Population Estimates							Estimates Base	Census 2000
Geographic area	July 1, 2006	July 1, 2005	July 1, 2004	July 1, 2003	July 1, 2002	July 1, 2001	July 1, 2000	April 1, 2000	April 1, 2000
Pennsylvania	12,440,621	12,405,348	12,377,381	12,351,381	12,321,644	12,295,929	12,286,905	12,281,054	12,281,054
COUNTY									
Adams County	101,105	99,746	98,237	96,236	94,512	92,907	91,620	91,292	91,292
Allegheny County	1,223,411	1,233,036	1,245,789	1,257,062	1,265,413	1,272,507	1,279,868	1,281,666	1,281,666
Armstrong County	70,096	70,527	71,304	71,571	71,784	72,011	72,321	72,392	72,392
Beaver County	175,736	176,825	177,896	178,666	179,079	179,909	181,160	181,412	181,412
Bedford County	49,927	49,862	49,966	49,924	49,862	49,886	50,045	49,984	49,984
Berks County	401,149	396,236	391,172	385,982	381,619	377,747	374,614	373,661	373,638
Blair County	126,494	126,572	127,095	127,323	127,600	128,501	129,066	129,144	129,144
Bradford County	62,471	62,504	62,445	62,530	62,701	62,690	62,796	62,761	62,761
Bucks County	623,205	619,772	616,533	612,369	609,085	604,199	599,525	597,632	597,635
Butler County	182,901	181,526	180,483	179,556	178,110	176,102	174,598	174,081	174,083
Cambria County	146,967	147,804	148,512	149,303	150,303	151,231	152,251	152,598	152,598
Cameron County	5,489	5,593	5,657	5,777	5,844	5,905	5,943	5,974	5,974
Carbon County	62,567	61,876	60,992	60,243	59,721	59,236	58,846	58,802	58,802
Centre County	140,953	140,313	139,934	139,754	138,660	136,265	135,845	135,758	135,758
Chester County	482,112	473,723	465,761	457,477	449,977	442,418	435,869	433,501	433,501
Clarion County	40,385	40,388	40,459	41,282	41,207	41,592	41,744	41,765	41,765
Clearfield County	82,442	82,634	82,816	82,994	83,315	83,217	83,392	83,382	83,382
Clinton County	37,232	37,233	37,273	37,416	37,526	37,768	37,926	37,910	37,914
Columbia County	65,014	64,792	64,844	64,737	64,476	64,317	64,111	64,148	64,151
Crawford County	89,389	89,484	89,683	89,889	90,071	90,224	90,394	90,366	90,366
Cumberland County	226,117	223,017	220,974	219,336	217,490	215,187	213,988	213,674	213,674
Dauphin County	254,176	252,949	252,609	252,893	252,572	251,625	251,839	251,798	251,798
Delaware County	555,996	554,393	553,528	553,632	553,256	553,075	552,250	551,974	550,864
Elk County	33,179	33,473	33,920	34,181	34,514	34,820	35,046	35,112	35,112
Erie County	279,811	280,184	280,833	282,892	282,475	281,749	280,729	280,843	280,843
Fayette County	145,760	146,206	146,612	146,076	146,665	147,277	148,527	148,644	148,644
Forest County	6,506	6,507	5,773	4,935	4,976	5,034	4,940	4,946	4,946
Franklin County	139,991	137,273	134,629	132,754	131,502	130,296	129,556	129,313	129,313
Fulton County	14,783	14,655	14,564	14,518	14,333	14,221	14,266	14,261	14,261
Greene County	40,432	40,408	39,979	40,183	40,462	40,453	40,688	40,672	40,672
Huntingdon County	45,771	45,772	45,832	45,862	45,801	45,607	45,600	45,586	45,586
Indiana County	88,234	88,481	88,849	89,244	89,047	89,280	89,537	89,605	89,605
Jefferson County	45,725	45,716	45,788	45,896	45,786	45,838	45,948	45,932	45,932
Juniata County	23,512	23,412	23,303	23,104	22,894	22,790	22,857	22,821	22,821
Lackawanna County	209,728	209,622	209,732	210,104	210,954	212,183	212,935	213,295	213,295
Lancaster County	494,486	489,936	486,002	482,159	478,285	474,562	471,756	470,635	470,658
Lawrence County	91,795	92,412	92,958	93,393	93,762	93,991	94,628	94,645	94,643
Lebanon County	126,883	125,429	124,064	122,807	121,577	120,983	120,440	120,327	120,327
Lehigh County	335,544	330,168	325,244	321,105	317,170	314,903	312,691	312,090	312,090
Luzerne County	313,020	312,795	312,765	313,621	314,489	315,899	318,629	319,252	319,250
Lycoming County	117,668	118,102	118,375	118,481	118,741	119,222	119,959	120,048	120,044
McKean County	44,065	44,239	44,643	45,017	45,455	45,280	45,803	45,936	45,936
Mercer County	118,551	119,115	119,547	119,753	119,729	120,001	120,197	120,293	120,293
Mifflin County	46,057	46,085	46,118	46,285	46,487	46,499	46,501	46,486	46,486
Monroe County	165,685	162,415	158,474	154,217	149,072	144,000	139,844	138,687	138,687
Montgomery									

Geographic area	Population Estimates							Estimates Base	Census 2000
	July 1, 2006	July 1, 2005	July 1, 2004	July 1, 2003	July 1, 2002	July 1, 2001	July 1, 2000	April 1, 2000	April 1, 2000
County	775,688	774,666	772,628	770,037	764,242	758,419	751,010	748,987	750,097
Montour County	17,934	17,983	17,994	18,111	18,180	18,308	18,255	18,239	18,236
Northampton County	291,306	287,334	283,312	278,141	273,776	269,731	267,510	267,069	267,066
Northumberland County	91,654	92,280	92,666	93,123	93,425	93,751	94,481	94,556	94,556
Perry County	45,087	44,724	44,526	44,248	43,911	43,797	43,620	43,602	43,602
Philadelphia County	1,448,394	1,456,350	1,465,475	1,473,364	1,485,249	1,497,897	1,513,655	1,517,550	1,517,550
Pike County	58,195	56,180	53,939	52,128	50,040	48,181	46,653	46,302	46,302
Potter County	17,568	17,728	17,929	18,091	18,155	18,096	18,146	18,080	18,080
Schuylkill County	147,405	146,996	147,159	147,716	148,725	149,287	150,149	150,334	150,336
Snyder County	38,226	37,949	38,079	37,933	37,907	37,780	37,553	37,546	37,546
Somerset County	78,508	78,796	79,238	79,608	79,592	79,477	80,043	80,023	80,023
Sullivan County	6,277	6,361	6,435	6,452	6,529	6,538	6,563	6,556	6,556
Susquehanna County	41,889	41,943	41,943	41,887	41,945	42,256	42,256	42,238	42,238
Tioga County	41,137	41,382	41,638	41,597	41,586	41,524	41,361	41,373	41,373
Union County	43,387	43,171	42,884	42,319	42,196	42,098	41,666	41,624	41,624
Venango County	55,488	55,938	56,116	56,542	56,861	57,162	57,477	57,565	57,565
Warren County	41,742	41,973	42,444	42,778	43,170	43,731	43,797	43,863	43,863
Washington County	206,432	206,418	205,003	204,599	203,694	203,523	203,049	202,897	202,897
Wayne County	50,929	50,529	49,577	49,083	48,446	48,104	47,927	47,722	47,722
Westmoreland County	366,440	367,133	367,530	368,166	368,168	369,096	369,838	369,993	369,993
Wyoming County	28,093	28,122	28,154	28,099	27,983	28,102	28,031	28,080	28,080
York County	416,322	408,182	400,746	394,820	389,505	385,664	382,777	381,751	381,751

Source: US Census Bureau, Population Estimates Program
More Tables and Information: Population Estimates Program
Note: The April 1, 2000 estimates base reflects changes to the Census 2000 population resulting from legal boundary updates as of January 1 of the estimates year, other geographic program changes, and Count Question Resolution actions. All geographic boundaries for the July 1, 2006 population estimates series are defined as of January 1, 2006. An "(x)" in the Census 2000 field indicates a locality that was formed or incorporated after Census 2000 or was erroneously omitted from Census 2000. See Geographic Change Notes for additional information on these localities.

ECC Exhibit RQH-3

Virginia -- County
GCT-T1. Population Estimates
Data Set: 2006 Population Estimates

Note: For information on errors stemming from model error, sampling error, and nonsampling error, see: http://www.census.gov/popest/topics/methodology.

	Population Estimates							Estimates Base	Census 2000
Geographic area	July 1, 2006	July 1, 2005	July 1, 2004	July 1, 2003	July 1, 2002	July 1, 2001	July 1, 2000	April 1, 2000	April 1, 2000
Virginia	7,642,884	7,564,327	7,472,448	7,375,863	7,285,707	7,192,701	7,104,587	7,079,030	7,078,515
COUNTY									
Accomack County	39,345	39,307	39,182	39,033	38,868	38,631	38,395	38,305	38,305
Albemarle County	92,035	90,496	88,929	87,609	86,488	85,774	84,631	84,197	79,236
Alleghany County	16,600	16,681	16,716	16,739	16,952	17,043	17,172	17,215	12,926
Amelia County	12,502	12,208	11,927	11,694	11,708	11,594	11,479	11,400	11,400
Amherst County	32,239	32,004	31,869	31,864	31,788	32,015	31,899	31,894	31,894
Appomattox County	14,128	13,871	13,906	13,728	13,740	13,843	13,707	13,705	13,705
Arlington County	199,776	199,761	197,955	197,223	195,782	193,389	189,310	189,444	189,453
Augusta County	70,910	69,656	68,675	67,628	66,822	66,242	65,797	65,615	65,615
Bath County	4,814	4,901	4,963	5,020	5,047	5,041	5,042	5,048	5,048
Bedford County	66,507	64,999	63,723	62,630	61,767	61,122	60,574	60,302	60,371
Bland County	6,903	6,941	6,987	6,976	6,900	6,942	6,861	6,871	6,871
Botetourt County	32,228	31,909	31,736	31,498	31,183	30,699	30,605	30,530	30,496
Brunswick County	17,938	17,857	17,993	18,050	18,323	18,339	18,426	18,419	18,419
Buchanan County	24,409	24,690	25,108	25,544	26,024	26,381	26,823	26,978	26,978
Buckingham County	16,099	16,036	15,891	15,861	15,811	15,840	15,631	15,623	15,623
Campbell County	52,667	52,187	51,515	51,384	51,400	51,182	51,165	51,105	51,078
Caroline County	26,731	25,437	23,937	23,133	22,588	22,227	22,138	22,121	22,121
Carroll County	29,450	29,322	29,432	29,252	29,270	29,383	29,296	29,245	29,245
Charles City County	7,221	7,095	7,087	7,115	7,052	6,955	6,931	6,926	6,926
Charlotte County	12,491	12,426	12,345	12,364	12,479	12,398	12,457	12,471	12,472
Chesterfield County	296,718	288,423	281,949	276,050	270,534	265,331	260,892	259,782	259,903
Clarke County	14,565	14,154	13,814	13,409	13,213	13,050	12,709	12,652	12,652
Craig County	*5,179*	*5,132*	*5,166*	*5,125*	*5,076*	*5,076*	*5,099*	*5,091*	*5,091*
Culpeper County	44,622	42,454	40,121	38,542	36,888	35,468	34,498	34,265	34,262
Cumberland County	9,465	9,359	9,140	9,133	9,025	8,962	9,007	9,017	9,017
Dickenson County	16,182	16,260	16,190	16,186	16,217	16,260	16,352	16,395	16,395
Dinwiddie County	25,695	25,355	25,068	24,826	24,619	24,428	24,613	24,533	24,533
Essex County	10,633	10,490	10,308	10,265	10,103	10,022	9,993	9,989	9,989
Fairfax County	1,010,443	1,010,015	1,003,496	998,083	993,966	987,146	975,332	969,677	969,749
Fauquier County	66,170	64,834	63,021	61,069	59,450	57,424	55,586	55,145	55,139
Floyd County	14,789	14,652	14,449	14,348	14,251	14,136	13,951	13,874	13,874
Fluvanna County	25,058	24,714	23,828	23,188	22,261	21,218	20,237	20,047	20,047
Franklin County	50,784	50,172	49,607	48,989	48,487	47,982	47,463	47,283	47,286
Frederick County	71,187	68,984	66,644	64,750	62,919	61,216	59,599	59,209	59,209
Giles County	17,403	17,154	16,927	16,912	16,910	16,854	16,706	16,657	16,657
Gloucester County	38,293	37,750	37,122	36,597	35,886	35,316	34,885	34,780	34,780
Goochland County	20,085	19,275	18,653	18,124	17,680	17,289	16,936	16,863	16,863
Grayson County	16,159	16,286	16,414	16,526	16,682	16,680	16,887	16,881	17,917
Greene County	17,709	17,354	16,987	16,713	16,291	15,755	15,367	15,244	15,244
Greensville County	11,006	11,036	10,969	11,467	11,560	11,523	11,557	11,560	11,560
Halifax County	36,149	36,121	36,259	36,552	36,826	37,009	37,325	37,350	37,355
Hanover County	98,983	97,369	96,013	93,916	91,834	89,006	87,028	86,320	86,320
Henrico County	284,399	280,599	275,629	270,973	267,725	265,655	263,133	262,104	262,300

Geographic area	Population Estimates							Estimates Base	Census 2000
	July 1, 2006	July 1, 2005	July 1, 2004	July 1, 2003	July 1, 2002	July 1, 2001	July 1, 2000	April 1, 2000	April 1, 2000
Henry County	56,208	56,367	56,789	57,017	57,369	57,639	57,974	57,984	57,930
Highland County	2,510	2,481	2,459	2,511	2,465	2,548	2,534	2,536	2,536
Isle of Wight County	34,723	33,398	32,549	31,839	30,897	30,346	29,889	29,728	29,728
James City County	59,741	57,394	55,380	53,235	51,356	49,621	48,496	48,102	48,102
King and Queen County	6,903	6,795	6,748	6,564	6,568	6,601	6,621	6,630	6,630
King George County	21,780	20,659	19,321	18,506	17,791	17,157	16,914	16,803	16,803
King William County	15,381	14,712	14,313	14,097	13,782	13,496	13,208	13,146	13,146
Lancaster County	11,519	11,490	11,514	11,529	11,485	11,480	11,589	11,567	11,567
Lee County	23,787	23,696	23,719	23,696	23,585	23,357	23,546	23,589	23,589
Loudoun County	268,817	256,417	239,613	221,170	203,948	190,169	173,994	169,599	169,599
Louisa County	31,226	30,034	28,758	27,966	27,088	26,314	25,757	25,627	25,627
Lunenburg County	13,219	13,130	13,053	13,117	13,165	13,067	13,093	13,146	13,146
Madison County	13,613	13,358	13,108	13,039	12,973	12,704	12,560	12,519	12,520
Mathews County	9,184	9,131	9,144	9,215	9,259	9,303	9,205	9,207	9,207
Mecklenburg County	32,381	32,366	32,369	32,422	32,431	32,379	32,367	32,380	32,380
Middlesex County	10,615	10,493	10,435	10,278	10,086	10,069	9,968	9,932	9,932
Montgomery County	84,541	84,263	83,905	83,979	83,819	84,022	83,627	83,681	83,629
Nelson County	15,161	15,094	14,918	14,887	14,695	14,571	14,478	14,445	14,445
New Kent County	16,852	16,126	15,492	14,889	14,266	13,885	13,535	13,462	13,462
Northampton County	13,609	13,458	13,300	13,148	13,043	13,046	13,066	13,093	13,093
Northumberland County	12,820	12,829	12,781	12,681	12,578	12,334	12,283	12,268	12,259
Nottoway County	15,572	15,561	15,509	15,597	15,657	15,779	15,742	15,725	15,725
Orange County	31,740	30,249	28,841	28,022	27,274	26,547	26,020	25,881	25,881
Page County	24,104	23,836	23,628	23,612	23,349	23,242	23,207	23,175	23,177
Patrick County	19,212	19,216	19,176	19,213	19,304	19,411	19,423	19,407	19,407
Pittsylvania County	61,501	61,583	61,645	61,652	61,698	61,929	61,785	61,745	61,745
Powhatan County	27,649	26,627	25,789	25,019	24,241	23,156	22,616	22,377	22,377
Prince Edward County	20,530	20,441	20,175	19,770	20,004	19,635	19,698	19,720	19,720
Prince George County	36,184	36,497	36,350	36,088	35,120	33,851	33,188	33,108	33,047
Prince William County	357,503	349,155	336,232	322,195	310,766	297,637	283,824	280,813	280,813
Pulaski County	35,055	35,006	35,082	34,991	34,954	35,181	35,141	35,127	35,127
Rappahannock County	7,203	7,275	7,154	7,090	7,143	7,158	6,969	6,983	6,983
Richmond County	9,142	9,049	9,073	9,050	8,968	8,917	8,794	8,800	8,809
Roanoke County	90,482	88,875	87,708	86,989	86,431	85,954	85,736	85,692	85,778
Rockbridge County	21,337	21,271	21,067	20,954	20,837	20,812	20,849	20,808	20,808
Rockingham County	72,564	71,639	70,180	69,492	69,034	68,474	67,827	67,716	67,725
Russell County	28,790	28,830	28,795	28,940	28,944	29,071	29,290	29,258	30,308
Scott County	22,882	22,899	22,968	22,996	23,081	23,209	23,379	23,403	23,403
Shenandoah County	40,051	39,045	38,045	37,138	36,409	35,728	35,239	35,075	35,075
Smyth County	32,506	32,440	32,469	32,696	32,800	32,898	33,087	33,081	33,081
Southampton County	17,814	17,507	17,331	17,281	17,336	17,482	17,483	17,482	17,482
Spotsylvania County	119,529	116,312	111,622	107,455	102,474	96,708	91,577	90,393	90,395
Stafford County	120,170	117,968	114,357	109,182	104,181	98,363	93,576	92,446	92,446
Surry County	7,119	6,987	6,961	6,968	6,949	6,852	6,844	6,829	6,829
Sussex County	12,249	12,016	12,121	12,238	12,105	12,304	12,487	12,504	12,504
Tazewell County	44,608	44,532	44,577	44,420	44,265	44,144	44,456	44,598	44,598
Warren County	36,102	35,407	34,429	33,803	33,038	32,225	31,725	31,578	31,584
Washington County	51,984	51,918	51,711	51,384	51,289	51,222	51,161	51,103	51,103
Westmoreland County	17,188	17,139	16,944	16,955	16,715	16,630	16,685	16,718	16,718

	Population Estimates							Estimates Base	Census 2000
Geographic area	July 1, 2006	July 1, 2005	July 1, 2004	July 1, 2003	July 1, 2002	July 1, 2001	July 1, 2000	April 1, 2000	April 1, 2000
Wise County	41,905	41,958	41,818	41,845	41,799	41,913	42,164	42,205	40,123
Wythe County	28,640	28,363	28,047	27,942	27,817	27,670	27,634	27,599	27,599
York County	61,879	61,684	60,731	60,002	59,241	57,860	56,589	56,297	56,297
Alexandria city	136,974	137,602	136,635	135,547	134,709	133,121	129,173	128,292	128,283
Bedford city	6,249	6,270	6,279	6,303	6,346	6,393	6,384	6,381	6,299
Bristol city	17,496	17,391	17,359	17,332	17,088	17,305	17,298	17,367	17,367
Buena Vista city	6,457	6,412	6,476	6,347	6,294	6,336	6,361	6,349	6,349
Charlottesville city	40,315	40,358	40,745	40,678	40,992	40,640	40,020	40,088	45,049
Chesapeake city	220,560	218,219	214,390	209,460	205,228	202,949	200,362	199,184	199,184
Colonial Heights city	17,676	17,502	17,449	17,181	17,133	16,981	16,912	16,897	16,897
Covington city	6,073	6,145	6,269	6,289	6,332	6,398	6,304	6,303	6,303
Danville city	45,586	45,869	46,297	46,967	47,234	47,640	48,240	48,411	48,411
Emporia city	5,625	5,546	5,560	5,625	5,700	5,633	5,665	5,665	5,665
Fairfax city	22,422	21,822	21,937	22,034	21,822	21,902	21,649	21,570	21,498
Falls Church city	10,799	10,764	10,548	10,553	10,635	10,521	10,408	10,377	10,377
Franklin city	8,800	8,572	8,420	8,290	8,163	8,253	8,284	8,346	8,346
Fredericksburg city	21,273	20,672	20,732	20,032	20,003	19,738	19,311	19,279	19,279
Galax city	6,682	6,657	6,635	6,651	6,652	6,654	6,854	6,837	6,837
Hampton city	145,017	145,154	144,657	145,079	144,642	145,030	146,362	146,437	146,437
Harrisonburg city	40,885	40,419	40,602	40,747	40,992	40,621	40,340	40,453	40,468
Hopewell city	22,731	22,513	22,304	22,309	22,402	22,241	22,295	22,277	22,354
Lexington city	6,739	6,762	6,786	6,757	6,895	6,926	6,827	6,867	6,867
Lynchburg city	67,720	66,684	66,099	65,802	64,845	64,664	65,196	65,229	65,269
Manassas city	36,638	37,499	37,554	37,140	36,649	35,935	35,408	35,135	35,135
Manassas Park city	11,642	11,732	11,510	10,974	10,934	10,774	10,336	10,290	10,290
Martinsville city	14,945	14,900	14,862	15,008	15,087	15,293	15,327	15,365	15,416
Newport News city	178,281	178,869	181,252	180,788	179,430	179,432	180,539	180,697	180,150
Norfolk city	229,112	230,775	236,587	236,999	237,952	233,236	234,035	234,403	234,403
Norton city	3,643	3,646	3,778	3,899	3,929	3,900	3,887	3,908	3,904
Petersburg city	32,445	32,282	32,607	32,942	33,060	33,290	33,590	33,756	33,740
Poquoson city	11,918	11,790	11,663	11,727	11,606	11,491	11,584	11,566	11,566
Portsmouth city	101,377	99,772	99,056	98,903	99,178	99,538	100,402	100,565	100,565
Radford city	14,525	14,504	14,636	14,825	15,322	15,753	15,818	15,859	15,859
Richmond city	192,913	193,186	193,255	194,825	196,292	197,522	197,755	198,107	197,790
Roanoke city	91,552	91,842	92,178	92,553	93,104	94,470	94,744	94,911	94,911
Salem city	24,825	24,560	24,448	24,622	24,776	24,595	24,782	24,747	24,747
Staunton city	23,334	23,205	23,001	23,104	23,773	23,602	23,845	23,853	23,853
Suffolk city	81,071	78,787	76,334	73,265	69,699	66,609	64,214	63,677	63,677
Virginia Beach city	435,619	437,021	438,591	435,293	430,503	427,672	426,395	425,257	425,257
Waynesboro city	21,454	21,140	20,770	20,424	20,132	19,782	19,609	19,520	19,520
Williamsburg city	11,793	11,696	11,476	11,409	11,544	11,853	11,986	11,998	11,998
Winchester city	25,265	25,086	24,858	24,328	24,363	24,092	23,673	23,585	23,585

Source: US Census Bureau, Population Estimates Program
More Tables and Information: Population Estimates Program
Note: The April 1, 2000 estimates base reflects changes to the Census 2000 population resulting from legal boundary updates as of January 1 of the estimates year, other geographic program changes, and Count Question Resolution actions. All geographic boundaries for the July 1, 2006 population estimates series are defined as of January 1, 2006. An "(x)" in the Census 2000 field indicates a locality that was formed or incorporated after Census 2000 or was erroneously omitted from Census 2000. See Geographic Change Notes for additional information on these localities.

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

In re: Application of Trans-Allegheny Interstate Line Company	Docket Nos. A-110172, A-110172F0002-F0004 and G-00071229

TESTIMONY & COMMENTS OF
THE PENNSYLVANIA CHAPTER OF THE SIERRA CLUB

PART ONE

On behalf of more than 27,000 Pennsylvania members and their families, the Pennsylvania Chapter of the Sierra Club submits these comments in opposition to the Application of the Trans-Allegheny Interstate Line Company ("TrAILCo") requesting a certificate of public conveyance granting TrAILCo authority as a public utility, and regulatory authority, to site and construct one 500 kV transmission line, two substations, three 138 kV transmission lines, and related facilities (collectively the "proposed power lines"). It is expected that the PA Chapter will have additional testimony and comments to submit before the record closes in this matter.

The Pennsylvania Chapter of the Sierra Club's testimony and comments in opposition to the proposed power lines herein below are summarized as follows: (1) the proposed power lines will create an unnecessary and unreasonable risk of danger to the health and safety of the public; (2) the application is not in compliance with applicable statutes and regulations providing for the protection of the natural resources of this Commonwealth; (3) the proposed power lines will cause excessive adverse environmental impacts, (4) TrAILCo has not adequately considered the electric power

needs of the public, the state of available technology, and available alternatives; and (5). The proposed power lines are not necessary either.

Consider also, for example, the fact that TrAILCo has not adequately considered and presented alternative solutions for the alleged reliability issues, and projected growth in electricity demand. TrAILCo has not adequately identified, considered, or evaluated, wetlands and historical sites and the impacts that the proposed power lines may and will have on those wetlands and historical sites. Furthermore, TrAILCo does not even mention significant potential adverse health effects and cumulative impacts from the increased air pollution that will occur if these proposed power lines are built – including global warming and global climate change, mercury emissions, and dangerous particulate matter.

In addition, TrAILCo has not fulfilled its obligations under the Endangered Species Act and other federal laws and has not considered the statutory and executive actions underway in Pennsylvania to promote energy independence, conservation, electric energy demand-management, and alternative energy initiatives and undertakings.

I. The Proposed Power Line Creates An Unreasonable Risk Of Danger To Health And Safety, And Will Cause Excessive Adverse Environmental Impacts.

The proposed power lines will have significant – and devastating – adverse environmental impacts. In turn, these detrimental environmental impacts threaten the health and safety of Pennsylvania's residents and wildlife.

A. Air Pollution.

The construction of the proposed power lines will create increased air emissions and decrease the regional air quality. The proposed power lines will draw power from

generation plants on the Ohio River. Western Pennsylvania's residents suffer greatly from the sulfur, nitrogen, acid rain, particulate matter, and mercury deposition from these generation plants.

Many of the generating plants that will feed electricity to the proposed power lines are older power plants. In fact, some of the dirtiest and oldest power plants in the country can increase their production as a result of the proposed power lines. It is important to note that the compliance history of Allegheny Energy Supply's four largest generating facilities is terrible. These facilities include Hatfield's Ferry in Masontown, Pa (1972 megawatts), Harrison in Haywood, WV (1710 megawatts), Pleasants in Willow Island, WV (1300 megawatts) and Fort Martin in Maidsville, WV (1107 megawatts). The USEPA Enforcement and Compliance History Online system indicates that all four of these facilities are currently assigned "high priority violator" status for failure to comply with the Clean Air Act. http://www.epa-echo.gov.

"High Priority Violator" is the most serious level of Clean Air Act violation noted in EPA databases.

In addition, TrAILCo admits (in its West Virginia filing) that four new additional coal fired generating plants can be built if the proposed 500 kV line is approved. But TrAILCo does not analyze or discuss the true costs of coal, including the impact of these new coal-fired generation plants. One glaring omission is the urgent problem of global warming and climate change, which unequivocally reveals that coal sources are not really cheap energy.

> The harms associated with climate change are serious and well recognized. The Government's own objective assessment of the relevant science and a strong consensus among qualified experts indicate that global warming threatens, *inter alia*, a precipitate rise in sea levels, severe

> and irreversible changes to natural ecosystems, a significant reduction in winter snowpack with direct and important economic consequences, and increases in the spread of disease and the ferocity of weather events.

Massachusetts v. EPA, ___ U.S. ___ (April 2, 2007)(emphasis supplied), Syllabus at p.4; See also, *Id.*, Slip Op. at 7-8: The National Research Council's 2001 report titled Climate Change: An Analysis of Some Key Questions concluded that "[g]reenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures are, in fact, rising."

The PUC must consider the effects of the proposed power lines on global warming and climate change before approving TrAILCo's Application.

In addition, Western Pennsylvania is the national sink for sulfur, nitrogen, acid rain, particulate matter and mercury deposition from these plants. Particulate matter smaller than 2.5 microns ("PM 2.5") can be inhaled and causes lung cancer, emphysema, heart disease, and other life-threatening ailments. Recently the American Lung Association found that particulate matter pollution was increasing in the East. Terri E. Weaver, PhD, RN, and the American Lung Association Chair said:

> The increased particle pollution in the East is a particularly troubling trend, because exposure to particle pollution can not only take years off your life, it can threaten your life immediately. Even in many areas EPA currently considers safe, the science clearly shows that the air is too often dangerous to breathe, particularly for those with lung disease. Protecting Americans from potentially deadly air pollution means we need more protective federal standards, so that every community in the United States can have truly clean air.

Western Pennsylvania is one of the places the American Lung Association identified as an unhealthy place to breathe the air. The report goes on to say that "higher

soot levels in the East are linked to an increase in electricity generated by heavy polluting power plants." Any analysis of the human health and environmental impacts of proposed transmission lines must include an assessment of generating plants feeding the line, the effects of regional air pollution on citizens downwind of the plants, and the costs of these health impacts. See http://www.lungusa.org.

Another important area overlooked by TrAILCo involves mercury emissions. Mercury is a neurotoxin. Pennsylvania, like many other states, already "enjoys" a statewide fishing consumption advisory[1], primarily due to the regional extent of mercury contamination from air deposition. When rain washes mercury from the air into streams and lakes, the mercury is transformed to a highly toxic form that builds up in fish and bioaccumulates as it moves through the food chain. Mercury collects in the fish's muscle and cannot be reduced by cleaning and cooking methods. Individuals are then exposed to mercury through fish consumption. Women of childbearing age, pregnant women, breast feeding women, and their children are most vulnerable to harm.

The leading sources of this mercury in Western Pennsylvania are the power plants upwind of the region, including those that will feed power to the proposed power lines. Currently, the federal government does not require electric plants to control mercury at the source, even though it is a proven neurotoxin. Instead, mercury is part of a "cap and trade" program that allows older, dirtier plants to buy mercury credits and continue to pollute our environment with mercury. In Pennsylvania, the environmental and public health hazards of mercury have been more assertively addressed by the Commonwealth's promulgation of its own Mercury Reduction Rule:

[1] See http://www.fish.state.pa.us/fishpub/summary/00consumption_advisory.pdf

In February 2006, Governor Edward G. Rendell proposed for Pennsylvania a state-specific mercury reduction plan that protects the market for bituminous coal while ensuring vastly greater protections to improve the environment and keep residents healthy and safe. The Governor's plan, which took effect Sat. Feb. 17, 2007, supersedes a weaker rule advanced by the federal government.

This issue is of serious concern to many. Toxicologists, medical experts, labor leaders, teacher associations, religions, sportsmen and conservation organizations have weighed in with strong statements in support of the state rule.

A 60-day public comment period and three public hearings drew 10,934 responses on the Governor's plan --- a new record for a rulemaking in Pennsylvania. Of the 10,934 comments, fewer than three dozen opposed the state plan. The rest supported Governor Rendell's approach over an ineffective federal rule that does little to protect Pennsylvanians or clean up our environment.

Governor Rendell's plan will cut mercury emissions faster and more substantially than the federal plan, achieving at least 90 percent mercury reduction by 2015.[2]

B. The Effect On Designated Important Bird Areas (IBAs) And Other Bird Habitats.

Important Bird Areas, or IBAs, are sites that provide essential habitat for one or more species of bird. IBAs include sites for breeding, wintering, and/or migrating birds. IBAs may be a few acres or thousands of acres, but usually they are discrete sites that stand out from the surrounding landscape. Identification of a site as an IBA indicates it has unique importance for birds.[3] Such places are located on public as well as private lands and are highly valued and commonly utilized by Sierra Club members[4], associates,

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[2] See http://www.depweb.state.pa.us/mercury/site/default.asp See also, "State-Specific Plan to Control Toxic Mercury Emissions Takes Effect" ("Pennsylvania has 36 coal-fired power plants with 78 electric generating units that represent 20,000 megawatts of capacity. The commonwealth is second, behind only Texas, both in terms of total mercury emissions from all sources and the total amount of mercury pollution coming from power plants. Nearly 80 percent of the 5 tons of mercury emitted in Pennsylvania comes from power plants."). http://www.depweb.state.pa.us/news/cwp/view.asp?a=1278&q=518829

[3] http://www.audubon.org/bird/iba/iba_intro.html

[4] "Every bird song, wind song, and tremendous storm song of the rocks in the heart of the mountains is our song, our very own, and sings our love." John Muir (from Sierra Club, PA Chapter, Lehigh Valley Group homepage http://pennsylvania.sierraclub.org/lv/).

and friends, including people who historically enjoy those places with our members as our national and international guests.

According to the National Audubon Society, there are 72 Important Bird Areas (IBAs) in Pennsylvania. These IBAs are often interconnected or interrelated, and impacts to one can often affect one or more of the others, especially when migratory bird behaviors and habitats and cumulative effects are considered. The current list, including locations, of the designated IBAs in Pennsylvania can be found at http://iba.audubon.org/iba/stateIndex.do?state=US-PA . The national IBA list and locations can be found at http://www.audubon.org/bird/iba/ .[5] There are also many other important bird areas that are unlisted due to their presence on private property where they have not been formally inventoried. That circumstance does not lessen the importance of those unlisted areas to those bird populations.

The installation of new above-ground transmission lines poses significant threats to birds moving locally as well as those birds migrating regionally and internationally through the seasons.[6] This especially includes species listed by state or federal fish and wildlife agencies as threatened or endangered, as well as those acknowledged to be sensitive or vulnerable species.

Consider, for example, the bald eagle, which was just "de-listed" from the federal Endangered Species list by the U.S. Fish & Wildlife Service, but which remains listed as a threatened species by the Commonwealth of Pennsylvania under Pennsylvania law.

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[5] "The Important Bird Areas Program recognizes that coupled with global warming, habitat loss and fragmentation are the most serious threats facing populations of birds across America and around the world." http://www.audubon.org/bird/iba/ .

[6] Important Bird Areas often support a significant proportion of one or more species' total population. For example, in winter, the Niagara River hosts up to 20% of the entire population of Bonaparte's Gulls, making it a globally significant IBA. http://www.audubon.org/bird/iba/iba_intro.html .

There are only about 120 breeding pairs of bald eagles in Pennsylvania today, including 88 pairs which were introduced from Canada between 1983 and 1990.[7]

Electric transmission lines pose deadly threats to birds, especially raptors, many species of which are listed as threatened or endangered.[8] Adding more transmission lines compounds the harm. For example, to paraphrase recent testimony before Congress by Mike Daulton, Director of Conservation Policy for the National Audubon Society, some birds – such as grassland birds – avoid places with tall structures. Those species are adapted to open habitats where raptor predation is a major source of mortality. Tall structures, such as power line towers, in those habitats can give raptors a predation advantage by serving as perching sites, allowing them to survey the landscape in search of prey. Some ornithologists believe prey species are behaviorally programmed to perceive tall structures as a threat, and therefore avoid using habitats where tall structures exist. In cases where the birds affected are already in decline, the introduction of new electric transmission structures within those habitats could push them closer to extinction.[9]

Furthermore, herbicides and other chemicals and vegetation management techniques are commonly used to maintain constructed electric transmission line

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[7] Hopey, Don, "Bald eagles are flying high again," Pittsburgh Post-Gazette, June 28, 2007, at http://www.post-gazette.com/pg/07179/797809-113.stm ; Goa, Jerry, "Bald eagle no longer threatened species," Pittsburgh Tribune-Review, June 28, 2007 at http://www.pittsburghlive.com/x/tribunereview/s_514746.html . The PA Game Commission website on bald eagles, including a map of nesting sites (showing many within York County that will be affected, for example) is at http://www.pgc.state.pa.us/pgc/cwp/view.asp?a=458&q=152498

[8] See, *e.g.*, Williams, Ted, "Zapped!", Incite, Audubon Magazine, [n.d.] http://magazine.audubon.org/incite/incite0001.html .

[9] See, *e.g.*, Testimony of Mike Daulton, Director of Conservation Policy, National Audubon Society Before the Committee on Natural Resources Subcommittee on Fisheries, Wildlife and Oceans, Impacts of Wind Turbines on Birds and Bats (May 1, 2007), http://www.audubon.org/campaign/testimony_0507.html

corridors, and may adversely affect or otherwise disturb birds that nest or feed within and adjacent to those established corridors.

C. Pennsylvania's Economic, Cultural, Historical, Natural And Scenic Resources Will Be Adversely Affected By The Proposed Power Lines, And The Resulting Increased Air Pollution.

The following is a mere snapshot of Pennsylvania's economic, cultural, historical, natural, and scenic resources that will be adversely affected by additional air pollution, global warming, and/or additional coal production:

1. As of April 13, 2006, 323,366 acres of farmland had been preserved in 53 counties under the Commonwealth's agricultural land preservation programs.

2. Pennsylvania has 120 state parks on 283,000 acres, 20 state forests on 2.1 million acres of forestland in 48 of 67 counties, and 300 state game lands on 1.4 million acres. Pennsylvania's state forestland is one of the largest expanses of public forestland in the eastern United States.

3. Allegheny National Forest (500,000 acres), Delaware Water Gap National Recreational Area (70,000 acres), Gettysburg National Military Park (6,000 acres), Valley Forge National Park (4,000 acres) and Fort Necessity National Battlefield (900 acres).

4. Forty-two places in Pennsylvania are listed on the National Register of Historic Places.

See, Testimony of Pennsylvania House Majority Leader H. William DeWeese on April 25, 2007, and comments dated June 13, 2007). The proposed power lines will adversely affect the enjoyability, usability, and viewsheds of these protected areas.

In addition, as of December 31, 2005, 433,473 acres have been protected by Pennsylvania land trusts.[10] As of December 31, 2005, Pennsylvania's conservation

[10] See, e.g., http://conserveland.org/features/Conservelandnl/nl_spring2007#data.

easements totaled at least 151,484 acres. Another 44,813 acres are also directly owned by Pennsylvania land trusts. Id.

It is very disturbing to quantify the magnitude of the impacts posed by these proposed new intrusions and installations on the landscape of Pennsylvania – including but not limited to the millions of acres of state forest, park, and game lands, dozens of critical habitat areas, and tens of thousands of acres of legally conserved natural and agricultural lands that will be adversely affected. The figures do not begin to capture the great number, variety and richness of the many resources that will be affected, resources such as Pennsylvania's national parks, historic sites, memorials and recreation areas, the multitude of state, county, and local parks, public and private wildlife refuges, preserves and priority habitat areas, and other critically important community and regional resources. The proposed power lines threaten these important natural resources, irreplaceable agricultural lands, and treasured national, regional, and states' heritage sites.

Furthermore, the blazing of the proposed power lines will adversely affect the landscapes, fields, wetlands, riverine valleys, woodlands, and forests that are traditional cultural properties of the members of the Sierra Club and the citizens of the affected states such as Pennsylvania, or "Penn's Woods." The proposed power lines will fragment and dissect habitat, and introduce untold miles of separation and harmful fringe effects into large stretches of wooded lands and forest intersected by the proposed power lines. It will also interrupt wildlife travel corridors and subject wildlife to additional related and unnecessary stresses. This is particularly critical for sensitive, threatened and endangered species, but it applies to many, many more who rely on existing cover for security during foraging and natural travelways.

D. TrAILCo Has Not Adequately Identified Or Evaluated Affected Historical Sites.

TrAILCo is required to evaluate, and minimize, the impact of the proposed power lines on archaeological areas. 52 Pa. Code § 57.75(e)(3)(vii). In its Application, TrAILCo developed a GIS layer from the Cultural Resources Geographic Information System (CRGIS), but the report does not indicate that many archeological sites would be impacted. *See* Table 2-3 of the Route Evaluation and Environmental Report. TrAILCo indicates that only five "cultural resources" (all historic buildings) are in the vicinity of the proposed route. Section 4.8.2 of the Route Evaluation and Environment Report.

But TrAILCo's contractor apparently only considered historic buildings on the National Register as the only "cultural resources" of value. However, the route for the proposed power lines is an area rich with history, dating back to Paleo-Indian times (12,500 to 10,000 years before present) and extending forward in time to the French and Indian War. TrAILCo has failed to survey the entire proposed power line for archeological sites and traditional cultural properties, and has done nothing to minimize the impact to these areas and to wildlife should the project be approved. This alone should prohibit PUC approval of TrAILCo's application.

E. Electric And Magnetic Fields ("EMF").

The proposed power lines will be dangerous to the health and safety of the public, and to domestic, farm, and wild animals. For example, the lines will expose residents, visitors and animals to EMF's. EMFs have adverse impacts on human and animal health.

For example, TrAILCo's own expert admits that several studies have indicated a statistically significant increased risk of childhood leukemia for populations living near

high voltage power lines. Bailey Direct Testimony, 14. The EMFs from high voltage power lines have also been characterized by experts as a possible human carcinogen. *See id.*

II. The Application Is Not In Compliance With Applicable Statutes And Regulations Providing For The Protection Of The Natural Resources Of This Commonwealth.

A. Endangered Species Act.

The route of the proposed power lines will infiltrate the habitat of the Indiana Bat, a federally protected species. The United States Fish and Wildlife Service ("USFWS") is responsible for administering the Endangered Species Act. David Densmore, the supervisor of the Pennsylvania Field Office for the United States Fish and Wildlife Service, indicates that TrAILCo's Application does not comply with the Endangered Species Act:

> The project is within the range of the Indiana Bat (*Myotis sodalist*), a species that is federally listed as endangered. Due to the potential harm to this species, we will need additional project information, including project plans and a detailed project description indicating the acreage of forest disturbance, before we can determine whether there will be any potential adverse effects to Indiana bats that might be in the project area.

Densmore Letter, AP TrAIL Route Evaluation and Environmental Report. TrAILCo has not considered the impact of the proposed power lines on this protected species - or any other species that inhabits the route. Since TrAILCo has not complied with its obligations under the Endangered Species Act, its application must be denied.

B. TrAILCO Has Not Prepared An Environmental Impact Statement ("EIS").

Federal law requires that TrAILCo make a project-specific EIS. *See* 42 U.S.C. § 4332; 40 C.F.R. § 1508.18(b). Because FERC has already approved an incentive rate

increase for the project, an EIS must include a study of all possible alternatives, including a complete analysis and characterization of the supposed need for the proposed power lines, and alternatives to meet that need, if a need is demonstrated. Currently, the Application includes a "Route Evaluation Report and Environmental Report" that does not meet these requirements. The report does not comprehensively address the environmental, historical and cultural impacts, nor does it set forth a study of alternatives to the proposed power line.

C. Wetlands and Streams.

TrAILCo's Application does not sufficiently address the adverse environmental impact of the proposed power lines on wetlands. The Application relies on the National Wetlands Inventory (NWI) for an inventory of wetlands. The NWI is notorious for underestimating forested wetlands. Most wetlands in Western Pennsylvania are small, forested wetlands. The Commission should require TrAILCo to determine the existence and extent of local wetlands and other vulnerable water bodies (e.g. springs) through the use of field surveys along the proposed route and rights of way.

Similarly, TrAILCo used the National Hydrography Dataset ("NHD") to determine the amount of streams and rivers potentially impacted by the proposed power lines. However, the NHD uses a 1:100,000 scale mapping which severely underestimates the amount of streams in the area. The 1:24,000 scale dataset, not the 1:100,000 scale dataset, provides a much more accurate measure. For example, there are approximately 50,000 stream miles in Pennsylvania using the 1:100,000 scale mapping. Conversely, when PADEP used the 1:24,000 scale mapping, the total number of stream miles increased to over 80,000 miles.

III. TrAILCO Has Not Adequately Considered The State Of Available Technology And Available Alternatives.

Contrary to Pennsylvania law, TrAILCo has not considered reasonable alternatives. In determining whether to approve a proposed high voltage transmission line, the Commission must find that the line "will have minimum adverse environmental impact, considering . . . the available alternatives." 52 Pa. Code § 57.76(a)(4); see 52 Pa. Code § 57.57 (e)(4). TrAILCo has failed to demonstrate that there are no reasonable alternatives. That's because the fact is that there are reasonable alternatives to TrAILCo's proposals.

TrAILCo also ignores the following Pennsylvania laws and programs that stress the importance of evaluating and implementing alternative energy production methods, including:

- Alternative Energy Portfolio Standards Act of 2004[11]
- Funds for Renewable Energy[12] – Four funds were created as a result of the restructuring plans of five electric companies. The funds are designed to promote the development of sustainable and renewable energy programs and clean-air technologies on both a regional and statewide basis. The funds have provided more than $20 million in loans and $1.8 million in grants to over 100 projects.
- Governor Edward Rendell announced a comprehensive plan, including state assistance to purchase "smart meters" and efficient appliances and requiring power suppliers to invest in conservation. Governor Rendell proposes that increases in future energy demand be met in Pennsylvania through conservation rather than building new transmission lines and generating plants. [13]

[11] http://www.puc.state.pa.us/electric/electric_alt_energy.aspx

[12] http://www.puc.state.pa.us/electric/electric_renew_sus_energy.aspx

[13] http://www.puc.state.pa.us/electric/electric_alt_energy.aspx

TrAILCo's Application is deficient because it ignores alternatives such as energy efficiency, demand response and distributed generation.

TrAILCo and the Public Utility Commission must consider a broad range of alternatives to meet energy needs before allowing irreparable harm to exceptional historic, cultural and environmental resources.

For example:

1. ***Generate power close to demand*** – The proposed power line encourages the continuation of an old system. The energy produced by outdated and dirty coal fired plants in the Ohio River valley is transmitted over long distances to cities in the East Coast market. A diversified network of small, state-of-the-art clean plants near where the power is needed would result in a grid that is more efficient, more reliable, and more secure.

2. ***Improve existing lines*** -- Power companies can upgrade voltage and use new technologies to improve the capacity and the performance of transmission lines that are already in place, reducing or eliminating the need for new lines.

3. ***Manage demand*** – Power line congestion is caused not by average usage, but peak usage—for example, at 4:00 p.m. on the hottest day in August. Effective "demand-management" programs can use financial incentives and convenient technology to encourage people to use less electricity at peak times. These programs can work economically, at little or no inconvenience to consumers.

4. ***Strengthen energy conservation efforts*** – As we face the serious challenges of global climate change, Americans would do better to invest in initiatives that will reduce demand for energy rather than increase supply. Households can also make a difference one by one, dramatically reducing energy consumption by switching to compact fluorescent light bulbs and EnergyStar rated appliances. Using the best building materials and designs, new or renovated homes can achieve impressive energy efficiency at relatively low cost.

5. ***Let the market work:*** There are strong incentives to work for solutions like those listed above, but if the government intervenes in favor of a specific, "out-of-market" solution—the proposed power line—those incentives will be distorted. By giving utility companies the ability to charge rate payers the capital costs for new transmission projects and by

giving them access to federal condemnation authority, the government may be encouraging the most environmentally destructive solution.

Pennsylvania's elected officials have expressed a strong preference for these types of progressive approaches to energy demand. For example:

- May 11, 2007 correspondence from U.S. Congressman John P. Murtha (Pa.), provides that the federal government should seek more comprehensive energy solutions. Pennsylvania should not be required to pay for the East Coast's thirst for power. Pennsylvania will have to fund this project in the form of higher electricity rates. We have to find a fairer solution.

- May 11, 2007 correspondence from U.S. Congressman John P. Murtha (Pa.) discusses the potential health effects, adverse environmental impacts, decreased market values and marketability of surrounding land, and the ruin of picturesque landscapes.

- June 11, 2007 correspondence from J. Barry Stout to the Honorable Michael L. Waugh and the Honorable Jeffrey E. Piccola indicates that he introduced Pennsylvania Senate Resolution 129 to oppose the designation of a large "corridor" that could allow for federal approval of transmission lines, even if the state PUC determines that a particular transmission line should not be built.

- Governor Rendell has expressed concern that focusing on transmission lines alone fails to consider alternative technology and alternative routes, and interferes with Pennsylvania's comprehensive energy policies, including its leadership role in renewable energy and sustainable fuels.

- June 13, 2007 testimony of Senator J. Barry Stout opposing the DOE's NIETC designations. Among other things, Senator Stout was also concerned with the need to develop and promote more comprehensive means of addressing transmission congestion and energy solutions, such as enhanced energy conservation and efficiency measures, demand response, and more local generation.

- As Pennsylvania House Majority Leader H. William DeWeese testified, the proposed power lines ignore environmentally clean, renewable, energy-efficient, and cost-effective alternatives. There are alternatives to high voltage transmission lines. However, the failure of the federal government to require consistent investment in alternative energy has us here today discussing what may become another failed national energy policy.

Because TrAILCo has ignored its obligations to explore and evaluate alternatives to the proposed power lines, its applications should be denied.

IV. Conclusion.

For the above reasons, TrAILCo's applications must be denied. We reserve the right to supplement these comments and testimony while the hearing record is still open.

Respectfully submitted this 29 day of August 2007,

Tom Wolper /mw

Tom Wolper, Chair
Conservation Committee
PA Chapter, Sierra Club
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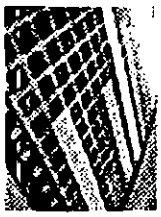
ECC Exhibit RQH-5



Loudoun County, Virginia
Selected Economic Characteristics: 2006
Data Set: 2006 American Community Survey
Survey: 2006 American Community Survey

NOTE. Although the American Community Survey (ACS) produces population, demographic and housing unit estimates, it is the Census Bureau's Population Estimates Program that produces and disseminates the official estimates of the population for the nation, states, counties, cities and towns and estimates of housing units for states and counties.

For more information on confidentiality protection, sampling error, nonsampling error, and definitions, see Survey Methodology.

Selected Economic Characteristics: 2006	Estimate	Margin of Error
EMPLOYMENT STATUS		
Population 16 years and over	**198,618**	**+/-896**
In labor force	151,198	+/-3,017
Civilian labor force	150,173	+/-3,162
Employed	146,976	+/-3,160
Unemployed	3,197	+/-1,003
Armed Forces	1,025	+/-582
Not in labor force	47,420	+/-3,034
Civilian labor force	**150,173**	**+/-3,162**
Unemployed	2.1%	+/-0.7
Females 16 years and over	**101,019**	**+/-750**
In labor force	70,442	+/-2,448
Civilian labor force	70,233	+/-2,529
Employed	68,293	+/-2,545
Own children under 6 years	**28,164**	**+/-1,048**
All parents in family in labor force	15,421	+/-1,700
Own children 6 to 17 years	**47,420**	**+/-1,138**
All parents in family in labor force	33,280	+/-2,058
COMMUTING TO WORK		
Workers 16 years and over	**144,442**	**+/-3,032**
Car, truck, or van -- drove alone	117,703	+/-3,314
Car, truck, or van -- carpooled	12,194	+/-2,439
Public transportation (excluding taxicab)	3,369	+/-1,019
Walked	1,938	+/-896
Other means	1,538	+/-826
Worked at home	7,700	+/-1,204
Mean travel time to work (minutes)	32.9	+/-1.1
Civilian employed population 16 years and over	**146,976**	**+/-3,160**
OCCUPATION		
Management, professional, and related occupations	80,788	+/-3,629
Service occupations	18,574	+/-2,608
Sales and office occupations	33,422	+/-3,242
Farming, fishing, and forestry occupations	143	+/-184
Construction, extraction, maintenance and repair occupations	8,218	+/-2,159
Production, transportation, and material moving occupations	5,831	+/-1,343
INDUSTRY		
Agriculture, forestry, fishing and hunting, and mining	1,174	+/-593
Construction	7,437	+/-1,545

Selected Economic Characteristics: 2006	Estimate	Margin of Error
Manufacturing	6,239	+/-1,672
Wholesale trade	2,953	+/-891
Retail trade	12,111	+/-2,155
Transportation and warehousing, and utilities	5,680	+/-1,319
Information	11,758	+/-2,310
Finance and insurance, and real estate and rental and leasing	11,923	+/-1,990
Professional, scientific, and management, and administrative and waste management services	38,274	+/-3,412
Educational services, and health care, and social assistance	21,240	+/-2,095
Arts, entertainment, and recreation, and accommodation, and food services	11,118	+/-2,209
Other services, except public administration	6,859	+/-1,850
Public administration	10,210	+/-1,760
CLASS OF WORKER		
Private wage and salary workers	115,923	+/-3,171
Government workers	23,715	+/-2,313
Self-employed workers in own not incorporated business	7,145	+/-1,266
Unpaid family workers	193	+/-218
INCOME AND BENEFITS (IN 2006 INFLATION-ADJUSTED DOLLARS)		
Total households	**83,011**	**+/-2,222**
Less than $10,000	1,975	+/-697
$10,000 to $14,999	1,479	+/-745
$15,000 to $24,999	2,509	+/-838
$25,000 to $34,999	3,587	+/-1,111
$35,000 to $49,999	6,422	+/-1,138
$50,000 to $74,999	12,046	+/-1,775
$75,000 to $99,999	13,821	+/-1,607
$100,000 to $149,999	19,909	+/-1,848
$150,000 to $199,999	11,683	+/-1,297
$200,000 or more	9,580	+/-1,118
Median household income (dollars)	99,371	+/-3,199
Mean household income (dollars)	118,442	+/-4,943
With earnings	76,697	+/-2,253
Mean earnings (dollars)	115,544	+/-3,926
With Social Security	9,696	+/-1,030
Mean Social Security income (dollars)	14,138	+/-1,127
With retirement income	10,960	+/-1,120
Mean retirement income (dollars)	31,246	+/-3,412
With Supplemental Security Income	765	+/-350
Mean Supplemental Security Income (dollars)	10,221	+/-4,741
With cash public assistance income	394	+/-382
Mean cash public assistance income (dollars)	N	N
With Food Stamp benefits in the past 12 months	999	+/-516
Families	**57,096**	**+/-2,735**
Less than $10,000	328	+/-224
$10,000 to $14,999	93	+/-124
$15,000 to $24,999	913	+/-395
$25,000 to $34,999	881	+/-469
$35,000 to $49,999	2,804	+/-847
$50,000 to $74,999	6,432	+/-1,165
$75,000 to $99,999	9,136	+/-1,149
$100,000 to $149,999	16,637	+/-1,571
$150,000 to $199,999	10,882	+/-1,285
$200,000 or more	8,990	+/-1,082
Median family income (dollars)	122,367	+/-5,001
Mean family income (dollars)	141,729	+/-6,717
Per capita income (dollars)	40,380	+/-1,657
Nonfamily households	**25,915**	**+/-2,437**
Median nonfamily income (dollars)	56,902	+/-9,674
Mean nonfamily income (dollars)	64,118	+/-5,081
Median earnings for workers (dollars)	49,410	+/-2,383
Median earnings for male full-time, year-round workers (dollars)	78,650	+/-4,722
Median earnings for female full-time, year-round workers (dollars)	51,554	+/-1,646

PERCENTAGE OF FAMILIES AND PEOPLE WHOSE INCOME IN THE PAST 12 MONTHS IS BELOW THE POVERTY LEVEL

Selected Economic Characteristics: 2006	Estimate	Margin of Error
All families	0.9%	+/-0.5
With related children under 18 years	1.2%	+/-0.8
With related children under 5 years only	1.0%	+/-1.2
Married couple families	0.8%	+/-0.5
With related children under 18 years	1.0%	+/-0.7
With related children under 5 years only	0.8%	+/-1.2
Families with female householder, no husband present	2.1%	+/-2.9
With related children under 18 years	2.8%	+/-3.8
With related children under 5 years only	7.8%	+/-16.7
All people	2.9%	+/-0.9
Under 18 years	1.8%	+/-1.1
Related children under 18 years	1.4%	+/-1.0
Related children under 5 years	1.4%	+/-1.6
Related children 5 to 17 years	1.4%	+/-1.2
18 years and over	3.3%	+/-1.1
18 to 64 years	2.9%	+/-1.0
65 years and over	8.3%	+/-4.5
People in families	1.3%	+/-0.8
Unrelated individuals 15 years and over	12.0%	+/-3.8

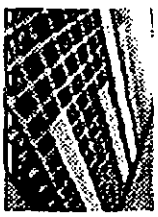
Source: U.S. Census Bureau, 2006 American Community Survey

Data are based on a sample and are subject to sampling variability. The degree of uncertainty for an estimate arising from sampling variability is represented through the use of a margin of error. The value shown here is the 90 percent margin of error. The margin of error can be interpreted roughly as providing a 90 percent probability that the interval defined by the estimate minus the margin of error and the estimate plus the margin of error (the lower and upper confidence bounds) contains the true value. In addition to sampling variability, the ACS estimates are subject to nonsampling error (for a discussion of nonsampling variability, see Accuracy of the Data). The effect of nonsampling error is not represented in these tables.

Notes:
·Employment and unemployment estimates may vary from the official labor force data released by the Bureau of Labor Statistics because of differences in survey design and data collection. For guidance on differences in employment and unemployment estimates from different sources go to Labor Force Guidance.
·Workers include members of the Armed Forces and civilians who were at work last week.
·Occupation codes are 4-digit codes, but are still based on Standard Occupational Classification 2000.
·Industry codes are 4-digit codes and are based on the North American Industry Classification System 2002. However, the Industry categories adhere to the guidelines issued in Clarification Memorandum No. 2, "NAICS Alternate Aggregation Structure for Use By U.S. Statistical Agencies," issued by the Office of Management and Budget.
·While the 2006 American Community Survey (ACS) data generally reflect the December 2005 Office of Management and Budget (OMB) definitions of metropolitan and micropolitan statistical areas, in certain instances the names, codes, and boundaries of the principal cities shown in ACS tables may differ from the OMB definitions due to differences in the effective dates of the geographic entities.

Explanation of Symbols:
1. An '**' entry in the margin of error column indicates that either no sample observations or too few sample observations were available to compute a standard error and thus the margin of error. A statistical test is not appropriate.
2. An '-' entry in the estimate column indicates that either no sample observations or too few sample observations were available to compute an estimate, or a ratio of medians cannot be calculated because one or both of the median estimates falls in the lowest interval or upper interval of an open-ended distribution.
3. An '-' following a median estimate means the median falls in the lowest interval of an open-ended distribution.
4. An '+' following a median estimate means the median falls in the upper interval of an open-ended distribution.
5. An '***' entry in the margin of error column indicates that the median falls in the lowest interval or upper interval of an open-ended distribution. A statistical test is not appropriate.
6. An '*****' entry in the margin of error column indicates that the estimate is controlled. A statistical test for sampling variability is not appropriate.
7. An 'N' entry in the estimate and margin of error columns indicates that data for this geographic area cannot be displayed because the number of sample cases is too small.
8. An '(X)' means that the estimate is not applicable or not available.

ECC Exhibit RQH-6



Washington County, Pennsylvania
Selected Economic Characteristics: 2006
Data Set: 2006 American Community Survey
Survey: 2006 American Community Survey

NOTE. Although the American Community Survey (ACS) produces population, demographic and housing unit estimates, it is the Census Bureau's Population Estimates Program that produces and disseminates the official estimates of the population for the nation, states, counties, cities and towns and estimates of housing units for states and counties.

For more information on confidentiality protection, sampling error, nonsampling error, and definitions, see Survey Methodology.

Selected Economic Characteristics: 2006	Estimate	Margin of Error
EMPLOYMENT STATUS		
Population 16 years and over	***159,788***	***+/-640***
In labor force	102,118	+/-2,403
Civilian labor force	102,018	+/-2,407
Employed	96,012	+/-2,627
Unemployed	6,006	+/-1,019
Armed Forces	100	+/-115
Not in labor force	67,670	+/-2,527
Civilian labor force	**102,018**	**+/-2,407**
Unemployed	5.9%	+/-1.0
Females 16 years and over	**89,658**	**+/-568**
In labor force	48,482	+/-1,644
Civilian labor force	48,466	+/-1,643
Employed	45,431	+/-1,752
Own children under 6 years	**12,282**	**+/-790**
All parents in family in labor force	7,047	+/-1,008
Own children 6 to 17 years	**28,140**	**+/-1,178**
All parents in family in labor force	19,993	+/-1,659
COMMUTING TO WORK		
Workers 16 years and over	**93,868**	**+/-2,643**
Car, truck, or van -- drove alone	78,102	+/-2,843
Car, truck, or van -- carpooled	8,229	+/-1,529
Public transportation (excluding taxicab)	1,561	+/-668
Walked	2,721	+/-910
Other means	948	+/-335
Worked at home	2,307	+/-713
Mean travel time to work (minutes)	25.7	+/-1.1
Civilian employed population 16 years and over	**96,012**	**+/-2,627**
OCCUPATION		
Management, professional, and related occupations	30,809	+/-2,291
Service occupations	14,977	+/-1,410
Sales and office occupations	26,143	+/-2,055
Farming, fishing, and forestry occupations	164	+/-140
Construction, extraction, maintenance and repair occupations	11,318	+/-1,390
Production, transportation, and material moving occupations	12,601	+/-1,557
INDUSTRY		
Agriculture, forestry, fishing and hunting, and mining	1,858	+/-580
Construction	8,728	+/-1,282

Selected Economic Characteristics: 2006	Estimate	Margin of Error
Manufacturing	10,828	+/-1,565
Wholesale trade	3,264	+/-852
Retail trade	12,253	+/-1,561
Transportation and warehousing, and utilities	4,958	+/-921
Information	1,292	+/-423
Finance and insurance, and real estate and rental and leasing	6,021	+/-1,211
Professional, scientific, and management, and administrative and waste management services	8,258	+/-1,254
Educational services, and health care, and social assistance	21,634	+/-2,229
Arts, entertainment, and recreation, and accommodation, and food services	8,417	+/-1,304
Other services, except public administration	5,005	+/-951
Public administration	3,496	+/-738
CLASS OF WORKER		
Private wage and salary workers	79,167	+/-2,878
Government workers	10,889	+/-1,553
Self-employed workers in own not incorporated business	5,682	+/-971
Unpaid family workers	274	+/-199
INCOME AND BENEFITS (IN 2006 INFLATION-ADJUSTED DOLLARS)		
Total households	82,422	+/-1,488
Less than $10,000	6,070	+/-1,070
$10,000 to $14,999	5,214	+/-926
$15,000 to $24,999	10,813	+/-1,123
$25,000 to $34,999	9,695	+/-1,352
$35,000 to $49,999	12,310	+/-1,341
$50,000 to $74,999	15,786	+/-1,387
$75,000 to $99,999	10,129	+/-1,181
$100,000 to $149,999	8,264	+/-1,160
$150,000 to $199,999	2,184	+/-728
$200,000 or more	1,957	+/-569
Median household income (dollars)	45,789	+/-2,580
Mean household income (dollars)	60,045	+/-2,656
With earnings	61,492	+/-1,903
Mean earnings (dollars)	62,141	+/-2,924
With Social Security	27,659	+/-1,047
Mean Social Security income (dollars)	14,992	+/-524
With retirement income	22,263	+/-1,302
Mean retirement income (dollars)	16,895	+/-1,944
With Supplemental Security Income	2,889	+/-632
Mean Supplemental Security Income (dollars)	8,122	+/-1,024
With cash public assistance income	1,953	+/-473
Mean cash public assistance income (dollars)	1,741	+/-451
With Food Stamp benefits in the past 12 months	5,176	+/-1,037
Families	53,969	+/-1,971
Less than $10,000	2,214	+/-579
$10,000 to $14,999	1,314	+/-464
$15,000 to $24,999	4,123	+/-653
$25,000 to $34,999	5,878	+/-903
$35,000 to $49,999	8,646	+/-1,044
$50,000 to $74,999	11,848	+/-1,376
$75,000 to $99,999	9,038	+/-1,073
$100,000 to $149,999	7,554	+/-1,130
$150,000 to $199,999	1,443	+/-486
$200,000 or more	1,911	+/-568
Median family income (dollars)	58,794	+/-2,380
Mean family income (dollars)	72,741	+/-3,666
Per capita income (dollars)	24,699	+/-1,040
Nonfamily households	28,453	+/-1,964
Median nonfamily income (dollars)	23,647	+/-2,753
Mean nonfamily income (dollars)	33,746	+/-3,085
Median earnings for workers (dollars)	26,554	+/-722
Median earnings for male full-time, year-round workers (dollars)	44,622	+/-3,525
Median earnings for female full-time, year-round workers (dollars)	29,447	+/-2,159
PERCENTAGE OF FAMILIES AND PEOPLE WHOSE INCOME IN THE PAST 12 MONTHS IS BELOW THE POVERTY LEVEL		

Selected Economic Characteristics: 2006	Estimate	Margin of Error
All families	6.8%	+/-1.3
With related children under 18 years	11.4%	+/-2.7
With related children under 5 years only	14.7%	+/-9.5
Married couple families	3.4%	+/-1.1
With related children under 18 years	4.3%	+/-2.0
With related children under 5 years only	8.0%	+/-7.1
Families with female householder, no husband present	25.2%	+/-6.5
With related children under 18 years	36.7%	+/-9.4
With related children under 5 years only	69.0%	+/-34.8
All people	10.0%	+/-1.6
Under 18 years	13.7%	+/-4.1
Related children under 18 years	13.6%	+/-4.1
Related children under 5 years	16.7%	+/-7.6
Related children 5 to 17 years	12.6%	+/-3.8
18 years and over	9.0%	+/-1.4
18 to 64 years	10.0%	+/-1.7
65 years and over	5.3%	+/-1.7
People in families	7.5%	+/-1.7
Unrelated individuals 15 years and over	21.0%	+/-4.2

Source: U.S. Census Bureau, 2006 American Community Survey

Data are based on a sample and are subject to sampling variability. The degree of uncertainty for an estimate arising from sampling variability is represented through the use of a margin of error. The value shown here is the 90 percent margin of error. The margin of error can be interpreted roughly as providing a 90 percent probability that the interval defined by the estimate minus the margin of error and the estimate plus the margin of error (the lower and upper confidence bounds) contains the true value. In addition to sampling variability, the ACS estimates are subject to nonsampling error (for a discussion of nonsampling variability, see Accuracy of the Data). The effect of nonsampling error is not represented in these tables.

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·Workers include members of the Armed Forces and civilians who were at work last week.
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3. An '-' following a median estimate means the median falls in the lowest interval of an open-ended distribution.
4. An '+' following a median estimate means the median falls in the upper interval of an open-ended distribution.
5. An '***' entry in the margin of error column indicates that the median falls in the lowest interval or upper interval of an open-ended distribution. A statistical test is not appropriate.
6. An '*****' entry in the margin of error column indicates that the estimate is controlled. A statistical test for sampling variability is not appropriate.
7. An 'N' entry in the estimate and margin of error columns indicates that data for this geographic area cannot be displayed because the number of sample cases is too small.
8. An '(X)' means that the estimate is not applicable or not available.

ECC Exhibit RQH-7

DP-3. Profile of Selected Economic Characteristics: 2000
Data Set: Census 2000 Summary File 3 (SF 3) - Sample Data
Geographic Area: **Greene County, Pennsylvania**

NOTE: Data based on a sample except in P3, P4, H3, and H4. For information on confidentiality protection, sampling error, *nonsampling error, definitions, and count corrections see http://factfinder.census.gov/home/en/datanotes/expsf3.htm.*

Subject	Number	Percent
EMPLOYMENT STATUS		
Population 16 years and over	32,829	100.0
In labor force	16,751	51.0
Civilian labor force	16,713	50.9
Employed	15,168	46.2
Unemployed	1,545	4.7
Percent of civilian labor force	9.2	(X)
Armed Forces	38	0.1
Not in labor force	16,078	49.0
Females 16 years and over	15,928	100.0
In labor force	7,222	45.3
Civilian labor force	7,218	45.3
Employed	6,699	42.1
Own children under 6 years	2,508	100.0
All parents in family in labor force	1,293	51.6
COMMUTING TO WORK		
Workers 16 years and over	14,878	100.0
Car, truck, or van -- drove alone	12,124	81.5
Car, truck, or van -- carpooled	1,634	11.0
Public transportation (including taxicab)	22	0.1
Walked	500	3.4
Other means	111	0.7
Worked at home	487	3.3
Mean travel time to work (minutes)	28.3	(X)
Employed civilian population 16 years and over	15,168	100.0
OCCUPATION		
Management, professional, and related occupations	3,770	24.9
Service occupations	2,633	17.4
Sales and office occupations	3,328	21.9
Farming, fishing, and forestry occupations	118	0.8
Construction, extraction, and maintenance occupations	2,831	18.7
Production, transportation, and material moving occupations	2,488	16.4
INDUSTRY		
Agriculture, forestry, fishing and hunting, and mining	1,231	8.1
Construction	1,420	9.4
Manufacturing	1,356	8.9
Wholesale trade	327	2.2
Retail trade	1,833	12.1
Transportation and warehousing, and utilities	1,236	8.1
Information	364	2.4
Finance, insurance, real estate, and rental and leasing	471	3.1
Professional, scientific, management, administrative, and waste management services	663	4.4
Educational, health and social services	3,529	23.3
Arts, entertainment, recreation, accommodation and food services	797	5.3
Other services (except public administration)	982	6.5
Public administration	959	6.3
CLASS OF WORKER		
Private wage and salary workers	11,646	76.8
Government workers	2,419	15.9
Self-employed workers in own not incorporated business	1,001	6.6

Subject	Number	Percent
Unpaid family workers	102	0.7
INCOME IN 1999		
Households	**15,081**	**100.0**
Less than $10,000	2,069	13.7
$10,000 to $14,999	1,595	10.6
$15,000 to $24,999	2,631	17.4
$25,000 to $34,999	2,222	14.7
$35,000 to $49,999	2,371	15.7
$50,000 to $74,999	2,566	17.0
$75,000 to $99,999	962	6.4
$100,000 to $149,999	519	3.4
$150,000 to $199,999	68	0.5
$200,000 or more	78	0.5
Median household income (dollars)	30,352	(X)
With earnings	10,570	70.1
Mean earnings (dollars)	41,186	(X)
With Social Security income	5,122	34.0
Mean Social Security income (dollars)	10,793	(X)
With Supplemental Security Income	1,063	7.0
Mean Supplemental Security Income (dollars)	6,340	(X)
With public assistance income	746	4.9
Mean public assistance income (dollars)	2,354	(X)
With retirement income	3,358	22.3
Mean retirement income (dollars)	11,970	(X)
Families	**10,642**	**100.0**
Less than $10,000	964	9.1
$10,000 to $14,999	748	7.0
$15,000 to $24,999	1,587	14.9
$25,000 to $34,999	1,685	15.8
$35,000 to $49,999	1,916	18.0
$50,000 to $74,999	2,289	21.5
$75,000 to $99,999	860	8.1
$100,000 to $149,999	476	4.5
$150,000 to $199,999	66	0.6
$200,000 or more	51	0.5
Median family income (dollars)	37,435	(X)
Per capita income (dollars)	14,959	(X)
Median earnings (dollars):		
Male full-time, year-round workers	32,189	(X)
Female full-time, year-round workers	21,332	(X)
POVERTY STATUS IN 1999 (below poverty level)		
Families	**1,393**	**(X)**
Percent below poverty level	(X)	13.1
With related children under 18 years	998	(X)
Percent below poverty level	(X)	19.6
With related children under 5 years	456	(X)
Percent below poverty level	(X)	25.3
Families with female householder, no husband present	**661**	**(X)**
Percent below poverty level	(X)	41.7
With related children under 18 years	543	(X)
Percent below poverty level	(X)	52.9
With related children under 5 years	247	(X)
Percent below poverty level	(X)	72.6
Individuals	**5,947**	**(X)**
Percent below poverty level	(X)	15.9
18 years and over	3,983	(X)
Percent below poverty level	(X)	13.9
65 years and over	648	(X)
Percent below poverty level	(X)	11.0
Related children under 18 years	1,933	(X)
Percent below poverty level	(X)	22.0
Related children 5 to 17 years	1,349	(X)
Percent below poverty level	(X)	20.1
Unrelated individuals 15 years and over	1,609	(X)

Subject	Number	Percent
Percent below poverty level	(X)	27.8

(X) Not applicable.
Detailed Occupation Code List (PDF 42KB)
Detailed Industry Code List (PDF 44KB)
User note on employment status data (PDF 63KB)
Source: U.S. Census Bureau, Census 2000 Summary File 3, Matrices P30, P32, P33, P43, P46, P49, P50, P51, P52, P53, P58, P62, P63, P64, P65, P67, P71, P72, P73, P74, P76, P77, P82, P87, P90, PCT47, PCT52, and PCT53

A report of Working Group I of the Intergovernmental Panel on Climate Change

Summary for Policymakers

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This Summary for Policymakers should be cited as:
IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Introduction

The Working Group I contribution to the IPCC Fourth Assessment Report describes progress in understanding of the human and natural drivers of climate change,[1] observed climate change, climate processes and attribution, and estimates of projected future climate change. It builds upon past IPCC assessments and incorporates new findings from the past six years of research. Scientific progress since the Third Assessment Report (TAR) is based upon large amounts of new and more comprehensive data, more sophisticated analyses of data, improvements in understanding of processes and their simulation in models and more extensive exploration of uncertainty ranges.

The basis for substantive paragraphs in this Summary for Policymakers can be found in the chapter sections specified in curly brackets.

Human and Natural Drivers of Climate Change

Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing,[2] which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate. Since the TAR, new observations and related modelling of greenhouse gases, solar activity, land surface properties and some aspects of aerosols have led to improvements in the quantitative estimates of radiative forcing.

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years (see Figure SPM.1). The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture. {2.3, 6.4, 7.3}

- Carbon dioxide is the most important anthropogenic greenhouse gas (see Figure SPM.2). The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm[3] in 2005. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores. The annual carbon dioxide concentration growth rate was larger during the last 10 years (1995–2005 average: 1.9 ppm per year), than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average: 1.4 ppm per year) although there is year-to-year variability in growth rates. {2.3, 7.3}

- The primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period results from fossil fuel use, with land-use change providing another significant but smaller contribution. Annual fossil carbon dioxide emissions[4] increased from an average of 6.4 [6.0 to 6.8][5] GtC (23.5 [22.0 to 25.0] $GtCO_2$) per year in the 1990s to 7.2 [6.9 to 7.5] GtC (26.4 [25.3 to 27.5] $GtCO_2$) per year in 2000–2005 (2004 and 2005 data are interim estimates). Carbon dioxide emissions associated with land-use change

[1] *Climate change* in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change, where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

[2] *Radiative forcing* is a measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Positive forcing tends to warm the surface while negative forcing tends to cool it. In this report, radiative forcing values are for 2005 relative to pre-industrial conditions defined at 1750 and are expressed in watts per square metre ($W\ m^{-2}$). See Glossary and Section 2.2 for further details.

[3] ppm (parts per million) or ppb (parts per billion, 1 billion = 1,000 million) is the ratio of the number of greenhouse gas molecules to the total number of molecules of dry air. For example, 300 ppm means 300 molecules of a greenhouse gas per million molecules of dry air.

[4] Fossil carbon dioxide emissions include those from the production, distribution and consumption of fossil fuels and as a by-product from cement production. An emission of 1 GtC corresponds to 3.67 $GtCO_2$.

[5] In general, uncertainty ranges for results given in this Summary for Policymakers are 90% uncertainty intervals unless stated otherwise, that is, there is an estimated 5% likelihood that the value could be above the range given in square brackets and 5% likelihood that the value could be below that range. Best estimates are given where available. Assessed uncertainty intervals are not always symmetric about the corresponding best estimate. Note that a number of uncertainty ranges in the Working Group I TAR corresponded to 2 standard deviations (95%), often using expert judgement.

CHANGES IN GREENHOUSE GASES FROM ICE CORE AND MODERN DATA

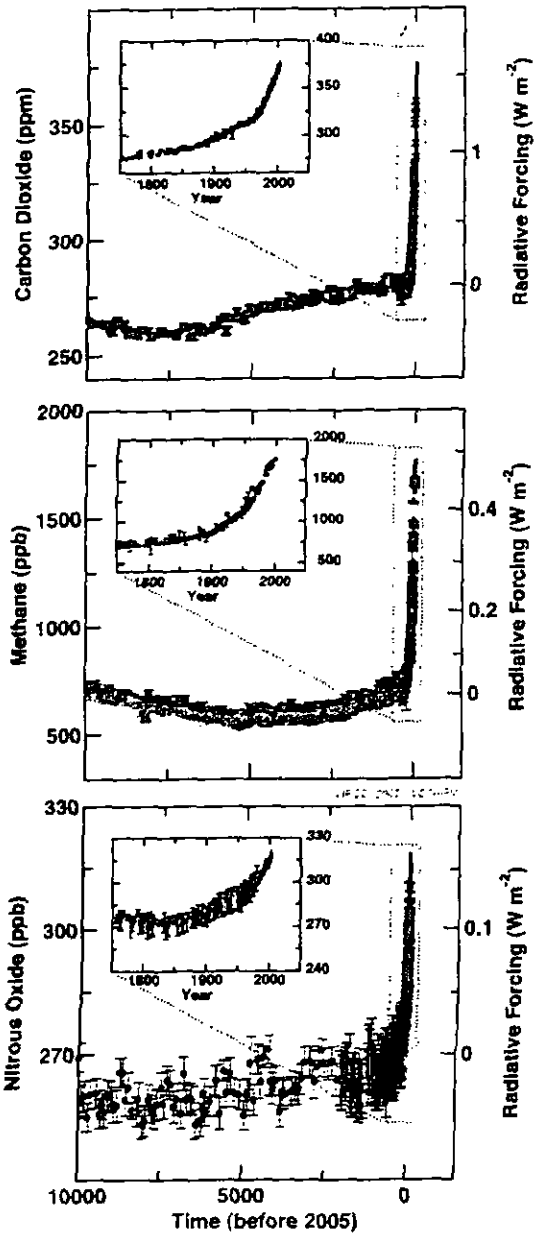

Figure SPM.1. Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels. (Figure 6.4)

are estimated to be 1.6 [0.5 to 2.7] GtC (5.9 [1.8 to 9.9] $GtCO_2$) per year over the 1990s, although these estimates have a large uncertainty. {7.3}

- The global atmospheric concentration of methane has increased from a pre-industrial value of about 715 ppb to 1732 ppb in the early 1990s, and was 1774 ppb in 2005. The atmospheric concentration of methane in 2005 exceeds by far the natural range of the last 650,000 years (320 to 790 ppb) as determined from ice cores. Growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. It is *very likely*[4] that the observed increase in methane concentration is due to anthropogenic activities, predominantly agriculture and fossil fuel use, but relative contributions from different source types are not well determined. {2.3, 7.4}

- The global atmospheric nitrous oxide concentration increased from a pre-industrial value of about 270 ppb to 319 ppb in 2005. The growth rate has been approximately constant since 1980. More than a third of all nitrous oxide emissions are anthropogenic and are primarily due to agriculture. {2.3, 7.4}

The understanding of anthropogenic warming and *cooling influences* on climate has improved since the TAR, leading to *very high confidence*[7] that the global average net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m^{-2} (see Figure SPM.2). {2.3., 6.5, 2.9}

- The combined radiative forcing due to increases in carbon dioxide, methane, and nitrous oxide is −2.30 [−2.07 to +2.53] W m^{-2}, and its rate of increase during the industrial era is *very likely* to have been unprecedented in more than 10,000 years (see Figures

[4] In this Summary for Policymakers, the following terms have been used to indicate the assessed likelihood, using expert judgement, of an outcome or a result: *Virtually certain* > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Unlikely* < 33%, *Very unlikely* < 10%, *Extremely unlikely* < 5% (see Box TS.1 for more details).

[7] In this Summary for Policymakers the following levels of confidence have been used to express expert judgements on the correctness of the underlying science: *very high confidence* represents at least a 9 out of 10 chance of being correct; *high confidence* represents about an 8 out of 10 chance of being correct (see Box TS.1).

SPM.1 and SPM.2). The carbon dioxide radiative forcing increased by 20% from 1995 to 2005, the largest change for any decade in at least the last 200 years. {2.3, 6.4}

- Anthropogenic contributions to aerosols (primarily sulphate, organic carbon, black carbon, nitrate and dust) together produce a cooling effect, with a total direct radiative forcing of –0.5 [–0.9 to –0.1] W m^{-2} and an indirect cloud albedo forcing of –0.7 [–1.8 to –0.3] W m^{-2}. These forcings are now better understood than at the time of the TAR due to improved *in situ*, satellite and ground-based measurements and more comprehensive modelling, but remain the dominant uncertainty in radiative forcing. Aerosols also influence cloud lifetime and precipitation. {2.4, 2.9, 7.5}

- *Significant anthropogenic contributions to radiative* forcing come from several other sources. Tropospheric ozone changes due to emissions of ozone-forming chemicals (nitrogen oxides, carbon monoxide, and hydrocarbons) contribute +0.35 [+0.25 to +0.65] W m^{-2}. The direct radiative forcing due to changes in halocarbons[a] is +0.34 [+0.31 to +0.37] W m^{-2}. Changes in surface albedo, due to land cover changes and deposition of black carbon aerosols on snow, exert

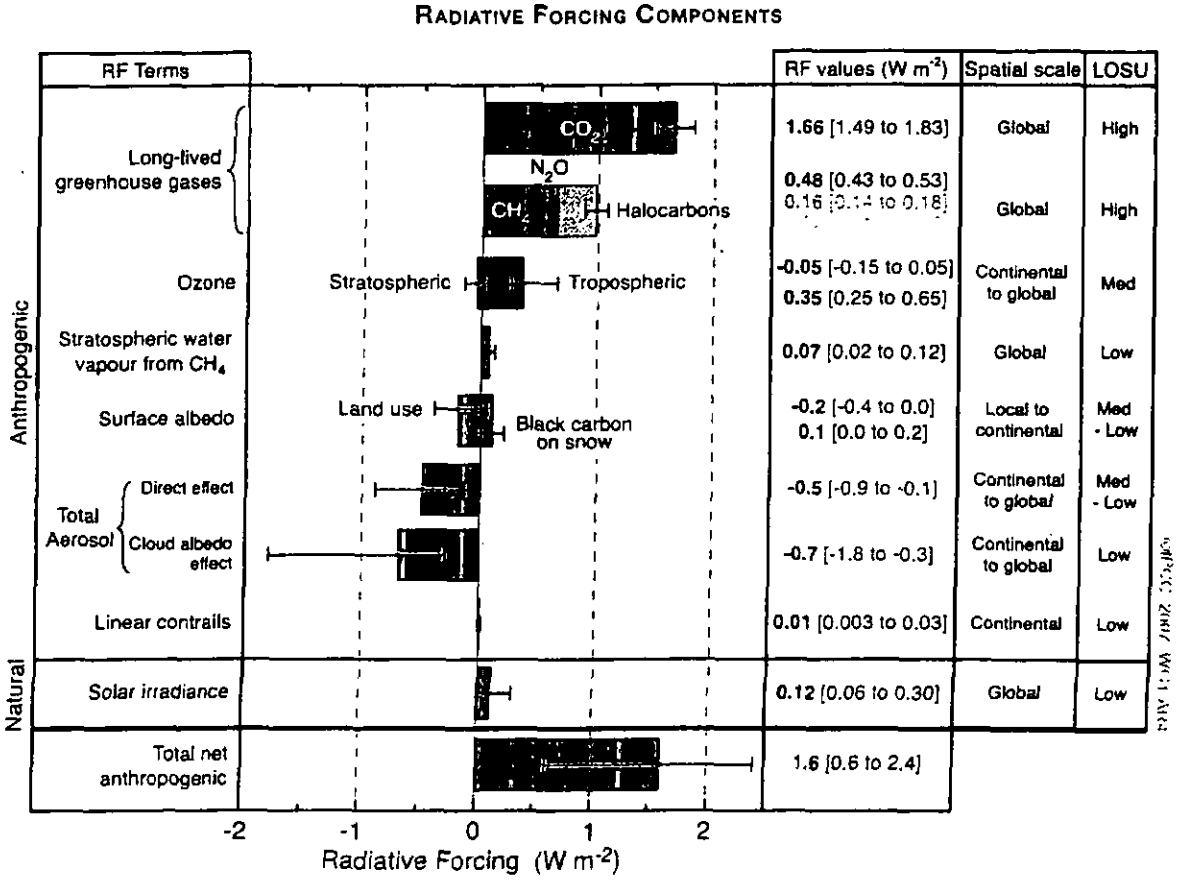

Figure SPM.2. *Global average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. The range for linear contrails does not include other possible effects of aviation on cloudiness. (2.9, Figure 2.20)*

[a] Halocarbon radiative forcing has been recently assessed in detail in *IPCC's Special Report on Safeguarding the Ozone Layer and the Global Climate System* (2005).

respective forcings of –0.2 [–0.4 to 0.0] and +0.1 [0.0 to +0.2] W m^{-2}. Additional terms smaller than ±0.1 W m^{-2} are shown in Figure SPM.2. {2.3, 2.5, 7.2}

- Changes in solar irradiance since 1750 are estimated to cause a radiative forcing of +0.12 [+0.06 to +0.30] W m^{-2}, which is less than half the estimate given in the TAR. {2.7}

Direct Observations of Recent Climate Change

Since the TAR, progress in understanding how climate is changing in space and in time has been gained through improvements and extensions of numerous datasets and data analyses, broader geographical coverage, better understanding of uncertainties, and a wider variety of measurements. Increasingly comprehensive observations are available for glaciers and snow cover since the 1960s, and for sea level and ice sheets since about the past decade. However, data coverage remains limited in some regions.

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (see Figure SPM.3). {3.2, 4.2, 5.5}

- *Eleven of the last twelve years (1995–2006)* rank among the 12 warmest years in the instrumental record of global surface temperature[6] (since *1850*). *The updated* 100-year linear trend (1906 to 2005) of 0.74°C [0.56°C to 0.92°C] is therefore larger than the corresponding trend for 1901 to 2000 given in the TAR of 0.6°C [0.4°C to 0.8°C]. The linear warming trend over the last 50 years (0.13°C [0.10°C to 0.16°C] per decade) is nearly twice that for the last *100* years. The total temperature increase from 1850–1899 to 2001–2005 is 0.76°C [0.57°C to 0.95°C]. Urban heat island effects *are real but local, and have a negligible influence* (less than 0.006°C per decade over land and zero over the oceans) on these values. {3.2}

- New analyses of balloon-borne and satellite measurements of lower- and mid-tropospheric *temperature show warming rates that are similar* to those of the surface temperature record and are consistent within their respective uncertainties, largely reconciling a discrepancy noted in the TAR. {3.2, 3.4}

- The average atmospheric water vapour content has increased since at least the 1980s over land and ocean as well as in the upper troposphere. The increase is *broadly consistent with the extra water vapour that* warmer air can hold. {3.4}

- Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes seawater to expand, contributing to sea level rise (see Table SPM.1). {5.2, 5.5}

- Mountain glaciers and snow cover have declined on average in both hemispheres. Widespread decreases in glaciers and ice caps have contributed to sea level *rise (ice caps do not include contributions* from the Greenland and Antarctic Ice Sheets). (See Table SPM.1.) {4.6, 4.7, 4.8, 5.5}

- New data since the TAR now show that losses from the *ice sheets of Greenland and Antarctica* have *very likely* contributed to sea level rise over 1993 to 2003 (see Table SPM.1). Flow speed has increased for some *Greenland and Antarctic outlet glaciers*, which drain ice from the interior of the ice sheets. The corresponding increased ice sheet mass loss has often followed thinning, reduction or loss of ice shelves or loss of floating glacier tongues. Such dynamical ice loss is sufficient to explain most of the Antarctic net mass loss and approximately half of the Greenland net mass loss. The remainder of the ice loss from Greenland has occurred because losses due to melting have exceeded accumulation due to snowfall. {4.6, 4.8, 5.5}

- Global average sea level *rose at an average rate of 1.8* [1.3 to 2.3] mm per year over 1961 to 2003. The rate was faster over 1993 to 2003: about 3.1 [2.4 to 3.8] mm per year. Whether the faster rate for 1993 to 2003 reflects decadal variability or an increase in the longer-term trend is unclear. There is *high confidence* that

[6] The average of near-surface air temperature over land and sea surface temperature.

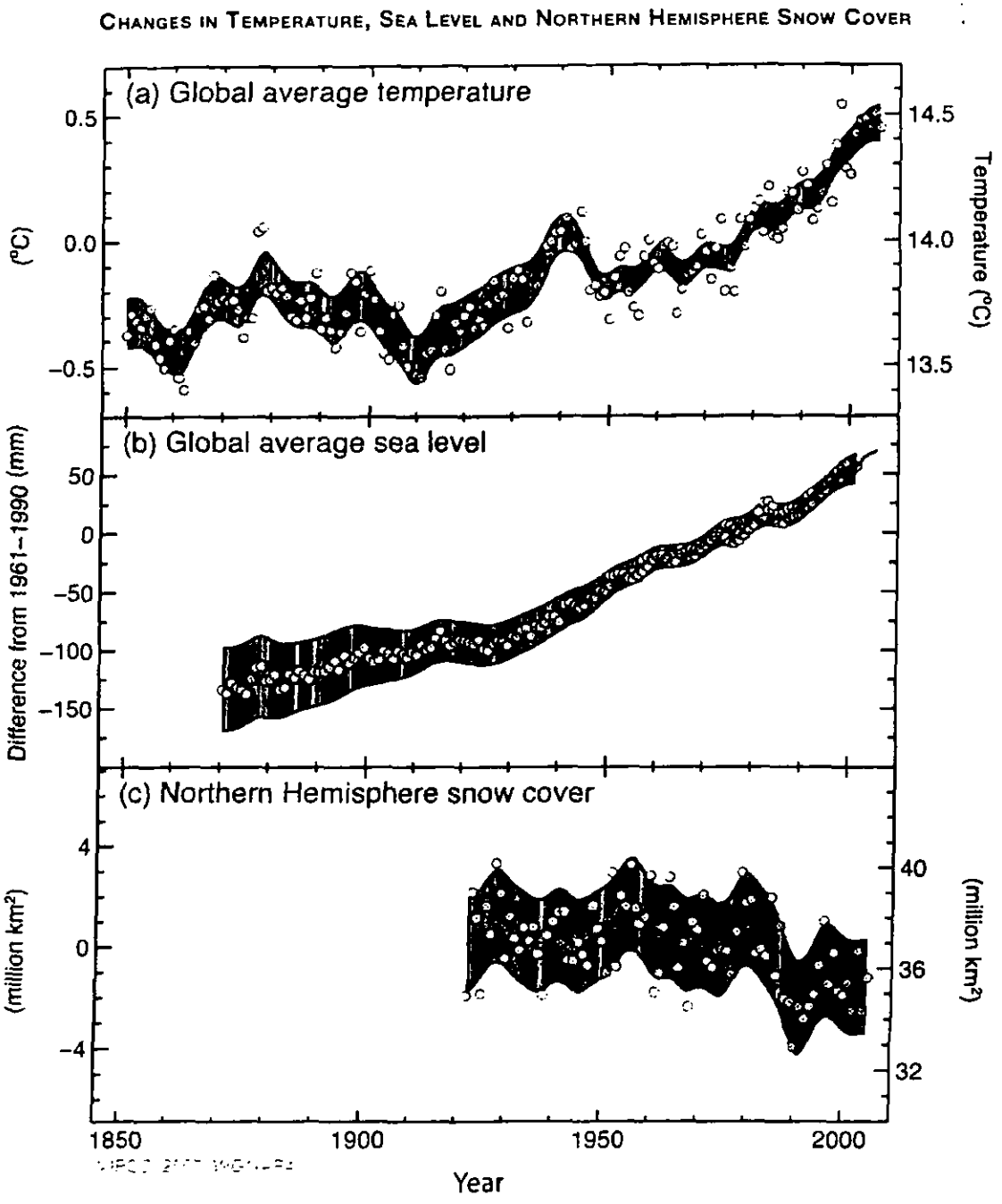

Figure SPM.3. *Observed changes in (a) global average surface temperature, (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961–1990. Smoothed curves represent decadal average values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). (FAQ 3.1, Figure 1, Figure 4.2, Figure 5.13)*

the rate of observed sea level rise increased from the 19th to the 20th century. The total 20th-century rise is *estimated to be* 0.17 [0.12 to 0.22] *m*. {5.5}

- For 1993 to 2003, the sum of the climate contributions is consistent within uncertainties with the total sea level rise that is directly observed (see Table SPM.1). These estimates are based on *improved* satellite and *in situ* data now available. For the period 1961 to 2003, the sum of climate contributions is estimated to be smaller than the observed sea level rise. The TAR reported a similar discrepancy for 1910 to 1990. {5.5}

At continental, regional and ocean basin scales, *numerous long-term changes in climate have* been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones.[10] {3.2, 3.3, 3.4, 3.5, 3.6, 5.2}

- Average arctic temperatures increased at almost twice the global average rate in the past 100 years. Arctic temperatures have high decadal variability, and a warm period was also observed from 1925 to 1945. {3.2}

- Satellite data since 1978 show that annual average arctic sea ice extent has shrunk by 2.7 [2.1 to 3.3]% per decade, with larger decreases in summer of 7.4 [5.0 to 9.8]% per decade. These values are consistent with those reported in the TAR. {4.4}

- Temperatures at the top of the permafrost layer have generally increased since the 1980s in the Arctic (by up to 3°C). The maximum area covered by seasonally frozen ground has decreased by about 7% in the Northern Hemisphere since 1900, with a decrease in spring of up to 15%. {4.7}

- Long-term trends from 1900 to 2005 have been observed in precipitation amount over many large regions.[11] Significantly increased precipitation has been observed in eastern parts of North and South America, northern Europe and northern and central Asia. Drying has been observed in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Precipitation is highly variable spatially and temporally, and data are limited in some regions. Long-term trends have not been observed for the other large regions assessed.[11] {3.3, 3.9}

- Changes in precipitation and evaporation over the oceans are suggested by freshening of mid- and high-latitude waters together with increased salinity in low-latitude waters. {5.2}

Table SPM.1. *Observed rate of sea level rise and estimated contributions from different sources. {5.5, Table 5.3}*

Source of sea level rise	Rate of sea level rise (mm per year) 1961–2003	1993–2003
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland Ice Sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic Ice Sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	2.8 ± 0.7
Observed total sea level rise	1.8 ± 0.5[a]	3.1 ± 0.7[a]
Difference (Observed minus sum of *estimated climate contributions*)	0.7 ± 0.7	0.3 ± 1.0

Table note:
[a] Data prior to 1993 are from tide gauges and after 1993 are from satellite altimetry.

[10] Tropical cyclones include hurricanes and typhoons.

[11] The assessed regions are those considered in the regional projections chapter of the TAR and in Chapter 11 of this report.

- Mid-latitude westerly winds have strengthened in both hemispheres since the 1960s. {3.5}

- More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics. Increased drying linked with higher temperatures and decreased precipitation has contributed to changes in drought. Changes in sea surface temperatures, wind patterns and decreased snowpack and snow cover have also been linked to droughts. {3.3}

- The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapour. {3.8, 3.9}

- Widespread changes in extreme temperatures have been observed over the last 50 years. Cold days, cold nights and frost have become less frequent, while hot days, hot nights and heat waves have become more frequent (see Table SPM.2). {3.8}

Table SPM.2. *Recent trends, assessment of human influence on the trend and projections for extreme weather events for which there is an observed late-20th century trend. {Tables 3.7, 3.8, 9.4; Sections 3.8, 5.5, 9.7, 11.2–11.9}*

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[e]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]	*Likely*[h]

Table notes:

[a] See Table 3.7 for further details regarding definitions.

[b] See Table TS.4, Box TS.5 and Table 9.4.

[c] Decreased frequency of cold days and nights (coldest 10%).

[d] Warming of the most extreme days and nights each year.

[e] Increased frequency of hot days and nights (hottest 10%).

[f] Magnitude of anthropogenic contributions not assessed. Attribution for these phenomena based on expert judgement rather than formal attribution studies.

[g] Extreme high sea level depends on average sea level and on regional weather systems. It is defined here as the highest 1% of hourly values of observed sea level at a station for a given reference period.

[h] Changes in observed extreme high sea level closely follow the changes in average sea level. {5.5} It is *very likely* that anthropogenic activity contributed to a rise in average sea level. {9.5}

In all scenarios, the projected global average sea level at 2100 is higher than in the reference period. {10.6} The effect of changes in regional weather systems on sea level extremes has not been assessed.

- There is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures. There are also suggestions of increased intense tropical cyclone activity in some other regions where concerns over data quality are greater. Multi-decadal variability and the quality of the tropical cyclone records prior to routine satellite observations in about 1970 complicate the detection of long-term trends in tropical cyclone activity. There is no clear trend in the annual numbers of tropical cyclones. {3.8}

Some aspects of climate have not been observed to change. {3.2, 3.8, 4.4, 5.3}

- A decrease in diurnal temperature range (DTR) was reported in the TAR, but the data available then extended only from 1950 to 1993. Updated observations reveal that DTR has not changed from 1979 to 2004 as both day- and night-time temperature have risen at about the same rate. The trends are highly variable from one region to another. {3.2}

- Antarctic sea ice extent continues to show interannual variability and localised changes but no statistically significant average trends, consistent with the lack of warming reflected in atmospheric temperatures averaged across the region. {3.2, 4.4}

- There is insufficient evidence to determine whether trends exist in the meridional overturning circulation (MOC) of the global ocean or in small-scale phenomena such as tornadoes, hail, lightning and dust-storms. {3.8, 5.3}

A Palaeoclimatic Perspective

Palaeoclimatic studies use changes in climatically sensitive indicators to infer past changes in global climate on time scales ranging from decades to millions of years. Such proxy data (e.g., tree ring width) may be influenced by both local temperature and other factors such as precipitation, and are often representative of particular seasons rather than full years. Studies since the TAR draw increased confidence from additional data showing coherent behaviour across multiple indicators in different parts of the world. However, uncertainties generally increase with time into the past due to increasingly limited spatial coverage.

Palaeoclimatic information supports the interpretation that the warmth of the last half century is unusual in at least the previous 1,300 years. The last time the polar regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 m of sea level rise. {6.4, 6.6}

- Average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years and *likely* the highest in at least the past 1,300 years. *Some recent studies indicate greater variability* in Northern Hemisphere temperatures than suggested in the TAR, particularly finding that cooler periods *existed in the 12th to 14th, 17th and 19th centuries.* Warmer periods prior to the 20th century are within the uncertainty range given in the TAR. {6.6}

- Global average sea level in the last interglacial period (about 125,000 years ago) was *likely* 4 to 6 m higher than during the 20th century, mainly due to the retreat of polar ice. Ice core data indicate that average polar temperatures at that time were 3°C to 5°C higher than present, because of differences in the Earth's orbit. The Greenland Ice Sheet and other arctic ice fields *likely* contributed no more than 4 m of the observed sea level rise. There may also have been a contribution from Antarctica. {6.4}

Understanding and Attributing Climate Change

This assessment considers longer and improved records, an expanded range of observations and improvements in the simulation of many aspects of climate and its variability based on studies since the TAR. It also considers the results of new attribution studies that have evaluated whether observed changes are quantitatively consistent with the expected response to external forcings and inconsistent with alternative physically plausible explanations.

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.[12] This is an advance since the TAR's conclusion that "most of the observed warming over the last 50 years is *likely* to have been due to the increase in greenhouse gas concentrations". Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns (see Figure SPM.4 and Table SPM.2). {9.4, 9.5}

- It is *likely* that increases in greenhouse gas concentrations alone would have caused more warming than observed because volcanic and anthropogenic aerosols have offset some warming that would otherwise have taken place. {2.9, 7.5, 9.4}

- The observed widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is *extremely unlikely* that global climate change of the past 50 years can be explained without external forcing, and *very likely* that it is not due to known natural causes alone. {4.8, 5.2, 9.4, 9.5, 9.7}

- Warming of the climate system has been detected in changes of surface and atmospheric temperatures in the upper several hundred metres of the ocean, and in contributions to sea level rise. Attribution studies have established anthropogenic contributions to all of these changes. The observed pattern of tropospheric warming and stratospheric cooling is *very likely* due to the combined influences of greenhouse gas increases and stratospheric ozone depletion. {3.2, 3.4, 9.4, 9.5}

- It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica (see Figure SPM.4). The observed patterns of warming, including greater warming over land than over the ocean, and their changes over time, are only simulated by models that include anthropogenic forcing. The ability of coupled climate models to simulate the observed temperature evolution on each of six continents provides stronger evidence of human influence on climate than was available in the TAR. {3.2, 9.4}

- Difficulties remain in reliably simulating and attributing observed temperature changes at smaller scales. On these scales, natural climate variability is relatively larger, making it harder to distinguish changes expected due to external forcings. Uncertainties in local forcings and feedbacks also make it difficult to estimate the contribution of greenhouse gas increases to observed small-scale temperature changes. {8.3, 9.4}

- Anthropogenic forcing is *likely* to have contributed to changes in wind patterns,[13] affecting extra-tropical storm tracks and temperature patterns in both hemispheres. However, the observed changes in the Northern Hemisphere circulation are larger than simulated in response to 20th-century forcing change. {3.5, 3.6, 9.5, 10.3}

- Temperatures of the most extreme hot nights, cold nights and cold days are *likely* to have increased due to anthropogenic forcing. It is *more likely than not* that anthropogenic forcing has increased the risk of heat waves (see Table SPM.2). {9.4}

[12] Consideration of remaining uncertainty is based on current methodologies.

[13] In particular, the Southern and Northern Annular Modes and related changes in the North Atlantic Oscillation. (3.6, 9.5, Box TS.2)

Global and Continental Temperature Change

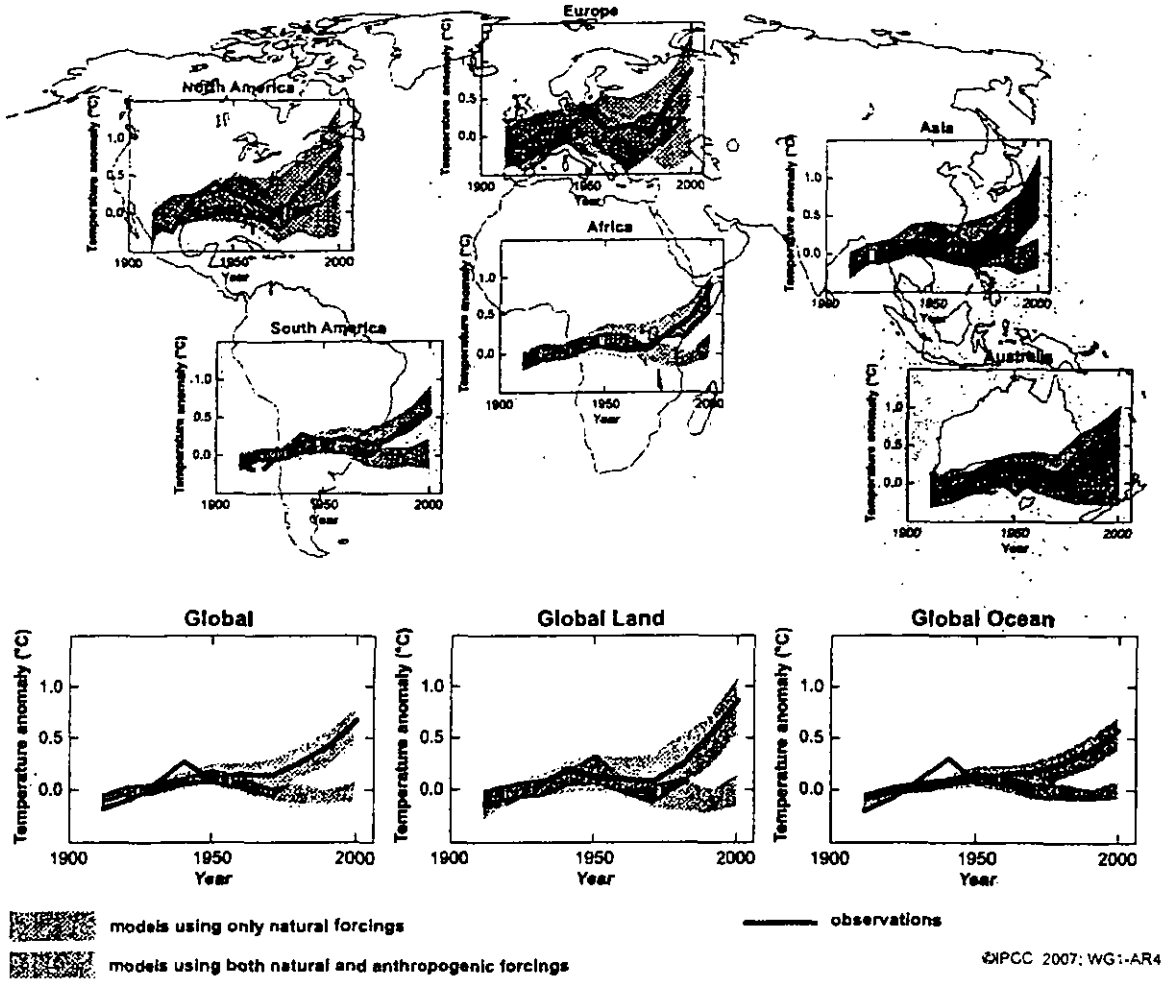

Figure SPM.4. *Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. (FAQ 9.2, Figure 1)*

Analysis of climate models together with constraints from observations enables an assessed *likely* range to be given for climate sensitivity for the first time and provides increased confidence in the understanding of the climate system response to radiative forcing. {6.6, 8.6, 9.6, Box 10.2}

- The equilibrium climate sensitivity is a measure of the climate system response to sustained radiative forcing. It is not a projection but is defined as the global average surface warming following a doubling of carbon dioxide concentrations. It is *likely* to be in the range 2°C to 4.5°C with a best estimate of about 3°C, and is *very unlikely* to be less than 1.5°C. Values substantially higher than 4.5°C cannot be excluded, but agreement of models with observations is not as good for those values. Water vapour changes represent the largest feedback affecting climate sensitivity and are now better understood than in the TAR. Cloud feedbacks remain the largest source of uncertainty. {8.6, 9.6, Box 10.2}

- It is *very unlikely* that climate changes of at least the seven centuries prior to 1950 were due to variability generated within the climate system alone. A significant fraction of the reconstructed Northern Hemisphere inter-decadal temperature variability over those centuries is *very likely* attributable to volcanic eruptions and changes in solar irradiance, and it is *likely* that anthropogenic forcing contributed to the early 20th-century warming evident in these records. {2.7, 2.8, 6.6, 9.3}

Projections of Future Changes in Climate

A major advance of this assessment of climate change projections compared with the TAR is the large number of simulations available from a broader range of models. Taken together with additional information from observations, these provide a quantitative basis for estimating likelihoods for many aspects of future climate change. Model simulations cover a range of possible futures including idealised emission or concentration assumptions. These include SRES[14] illustrative marker scenarios for the 2000 to 2100 period and model experiments with greenhouse gases and aerosol concentrations held constant after year 2000 or 2100.

For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. {10.3, 10.7}

- Since IPCC's first report in 1990, assessed projections have suggested global average temperature increases between about 0.15°C and 0.3°C per decade for 1990 to 2005. This can now be compared with observed values of about 0.2°C per decade, strengthening confidence in near-term projections. {1.2, 3.2}

- Model experiments show that even if all radiative forcing agents were held constant at year 2000 levels, a further warming trend would occur in the next two decades at a rate of about 0.1°C per decade, due mainly to the slow response of the oceans. About twice as much warming (0.2°C per decade) would be expected if emissions are within the range of the SRES scenarios. Best-estimate projections from models indicate that decadal average warming over each inhabited continent by 2030 is insensitive to the choice among SRES scenarios and is *very likely* to be at least twice as large as the corresponding model-estimated natural variability during the 20th century. {9.4, 10.3, 10.5, 11.2–11.7, Figure TS-29}

[14] SRES refers to the *IPCC Special Report on Emission Scenarios* (2000). The SRES scenario families and illustrative cases, which did not include additional climate initiatives, are summarised in a box at the end of this Summary for Policymakers. Approximate carbon dioxide equivalent concentrations corresponding to the computed radiative forcing due to anthropogenic greenhouse gases and aerosols in 2100 (see p. 823 of the TAR) for the SRES B1, AIT, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1250 and 1,550 ppm respectively. Scenarios B1, A1B and A2 have been the focus of model intercomparison studies and many of those results are assessed in this report.

Continued greenhouse gas emissions at or above *current rates would cause further warming and* induce many changes in the global climate system *during the 21st century that would very likely* be larger than those observed *during the 20th century.* {10.3}

- Advances in climate change modelling now enable best estimates and *likely* assessed uncertainty ranges to be given for projected warming for different emission scenarios. Results for different emission scenarios are provided explicitly in this report to avoid loss of this policy-relevant information. Projected global average surface warmings for the end of the *21st century* (2090–2099) relative to 1980–1999 are shown in Table SPM.3. These illustrate the differences between lower and higher SRES emission scenarios, and the projected warming uncertainty associated with these scenarios. {10.5}

- Best estimates and *likely* ranges for global average surface air warming for six SRES emissions marker scenarios are given in this assessment and are shown in Table SPM.3. For example, the *best estimate for* the low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C). Although these projections are broadly consistent with the span quoted in the TAR (1.4°C to 5.8°C), they are not directly comparable (see Figure SPM.5). The Fourth Assessment Report is more advanced as it provides best estimates and an assessed likelihood range for each of the marker scenarios. The new assessment of the *likely* ranges now relies on a larger number of climate models of increasing complexity and realism, as well as new information regarding the nature of feedbacks from the carbon cycle and constraints on climate response from observations. {10.5}

- Warming tends to reduce land and ocean uptake of atmospheric carbon dioxide, increasing the fraction of anthropogenic emissions that remains in the atmosphere. For the A2 scenario, for example, the climate-carbon cycle feedback increases the corresponding global average warming at 2100 by more than 1°C. Assessed upper ranges for temperature projections are larger than in the TAR (see Table SPM.3) mainly because the broader range of models now available suggests stronger climate-carbon cycle feedbacks. {7.3, 10.5}

- Model-based projections of global average sea level rise at the end of the 21st century (2090–2099) are shown in Table SPM.3. For each scenario, the midpoint of the range in Table SPM.3 is within 10% of the

Table SPM.3. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	*4.0*	*2.4 – 6.4*	*0.26 – 0.59*

Table notes:

[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).

[b] Year 2000 constant composition is derived from AOGCMs only.

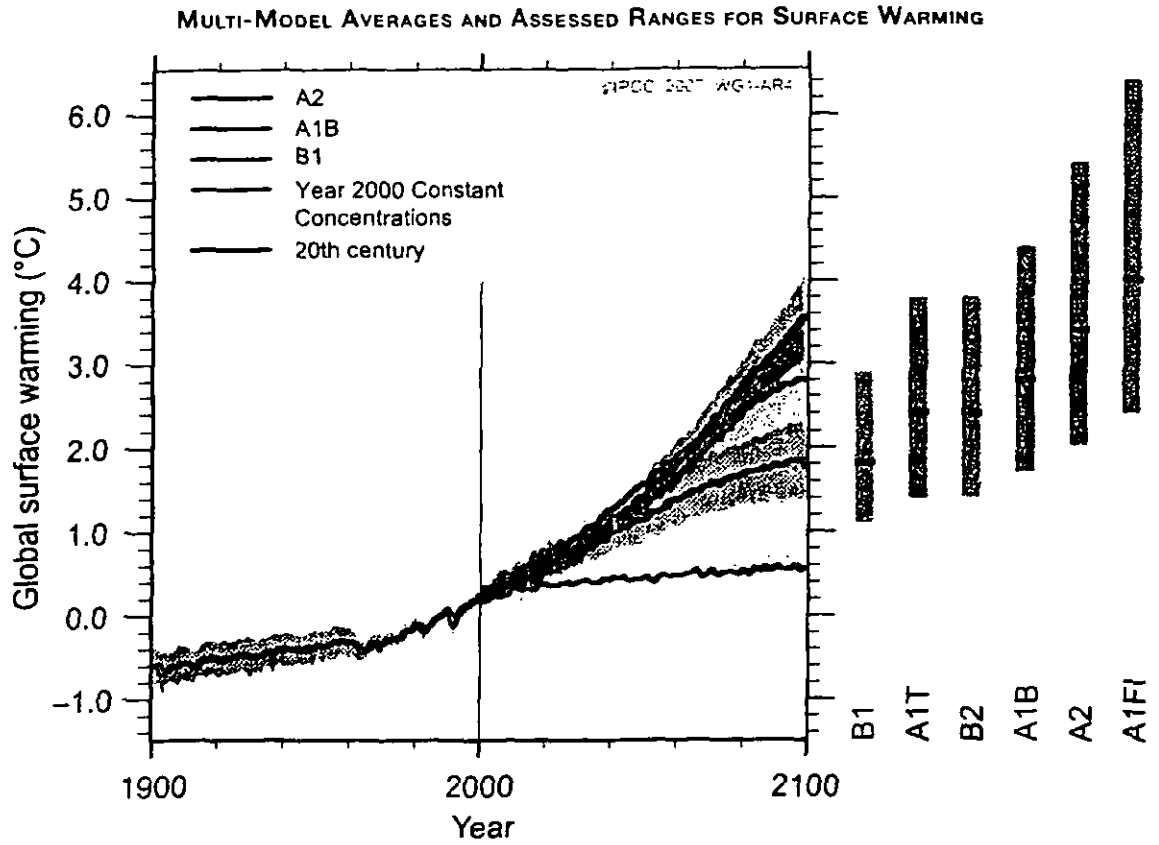

Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

TAR model average for 2090–2099. The ranges are narrower than in the TAR mainly because of improved information about some uncertainties in the projected contributions.[15] {10.6}

- Models used to date do not include uncertainties in climate-carbon cycle feedback nor do they include the full effects of changes in ice sheet flow, because a basis in published literature is lacking. The projections include a contribution due to increased ice flow from Greenland and Antarctica at the rates observed for 1993 to 2003, but these flow rates could increase or decrease in the future. For example, if this contribution were to grow linearly with global average temperature change, the upper ranges of sea level rise for SRES scenarios shown in Table SPM.3 would increase by 0.1 to 0.2 m. *Larger values cannot be excluded, but understanding of* these effects is too limited to assess their likelihood or *provide a best estimate or an upper bound for sea level* rise. {10.6}

- Increasing atmospheric carbon dioxide concentrations lead to increasing acidification of the ocean. Projections based on SRES scenarios give reductions in average global surface ocean pH[16] of between 0.14 and 0.35 units over the 21st century, adding to the present decrease of 0.1 units since pre-industrial times. {5.4, Box 7.3, 10.4}

[15] TAR projections were made for 2100, whereas projections in this report are for 2090–2099. The TAR would have had similar ranges to those in Table SPM.3 if it had treated the uncertainties in the same way.

[16] Decreases in pH correspond to increases in acidity of a solution. See Glossary for further details.

There is now higher confidence in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and of ice. {8.2, 8.3, 8.4, 8.5, 9.4, 9.5, 10.3, 11.1}

- Projected warming in the 21st century shows scenario-independent geographical patterns similar to those observed over the past several decades. Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean and parts of the North Atlantic Ocean (see Figure SPM.6). {10.3}

- Snow cover is projected to contract. Widespread increases in thaw depth are projected over most permafrost regions. {10.3, 10.6}

- Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES scenarios. In some projections, arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century. {10.3}

- It is *very likely* that hot extremes, heat waves and heavy precipitation events will continue to become more frequent. {10.3}

- Based on a range of models, it is *likely* that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures. There is less confidence in projections of a global decrease in numbers of tropical cyclones. The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period. {9.5, 10.3, 3.8}

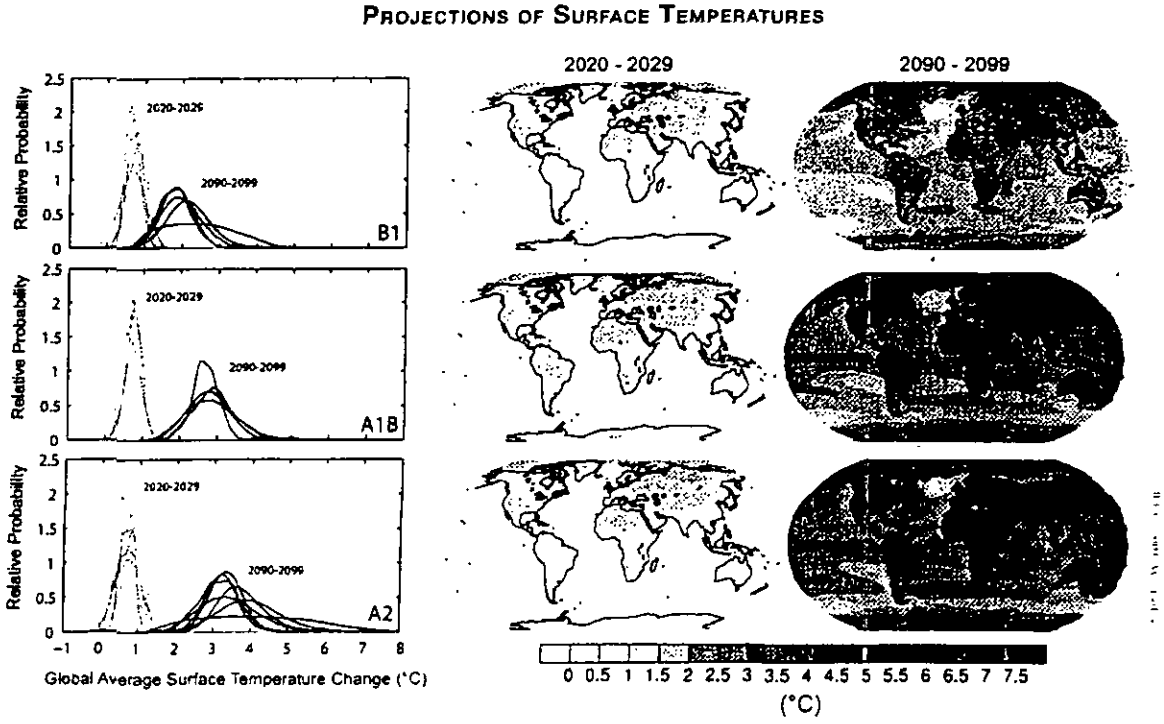

Figure SPM.6. *Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the AOGCM multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over the decades 2020–2029 (centre) and 2090–2099 (right). The left panels show corresponding uncertainties as the relative probabilities of estimated global average warming from several different AOGCM and Earth System Model of Intermediate Complexity studies for the same periods. Some studies present results only for a subset of the SRES scenarios, or for various model versions. Therefore the difference in the number of curves shown in the left-hand panels is due only to differences in the availability of results. {Figures 10.8 and 10.28}*

PROJECTED PATTERNS OF PRECIPITATION CHANGES

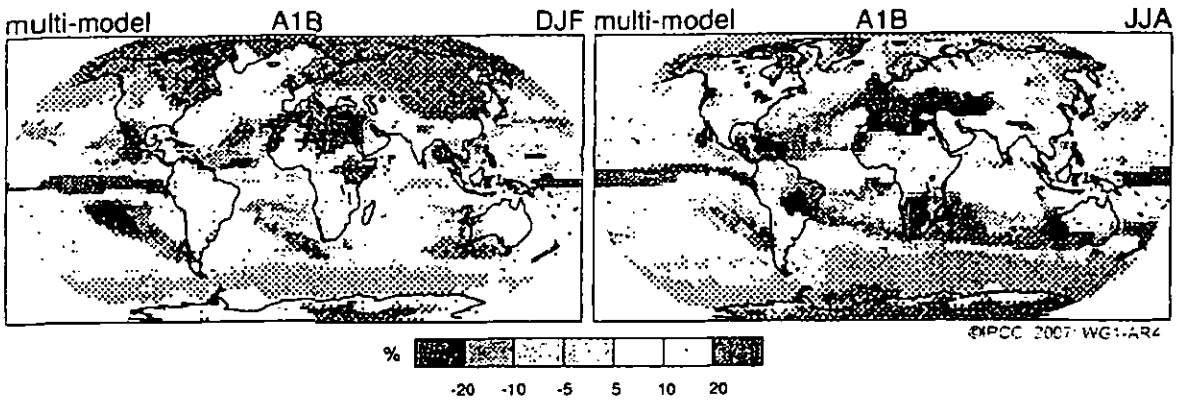

Figure SPM.7. *Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}*

- Extratropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation and temperature patterns, continuing the broad pattern of observed trends over the last half-century. {3.6, 10.3}

- Since the TAR, there is an improving understanding of projected patterns of precipitation. Increases in the amount of precipitation are *very likely* in high latitudes, while decreases are *likely* in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100, see Figure SPM.7), continuing observed patterns in recent trends. {3.3, 8.3, 9.5, 10.3, 11.2 to 11.9}

- Based on current model simulations, it is *very likely* that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down during the 21st century. The multi-model average reduction by 2100 is 25% (range from zero to about 50%) for SRES emission scenario A1B. Temperatures in the Atlantic region are projected to increase despite such changes due to the much larger warming associated with projected increases in greenhouse gases. It is *very unlikely* that the MOC will undergo a large abrupt transition during the 21st century. Longer-term changes in the MOC cannot be assessed with confidence. {10.3, 10.7}

Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilised. {10.4, 10.5, 10.7}

- Climate-carbon cycle coupling is expected to add carbon dioxide to the atmosphere as the climate system warms, but the magnitude of this feedback is uncertain. This increases the uncertainty in the trajectory of carbon dioxide emissions required to achieve a particular stabilisation level of atmospheric carbon dioxide concentration. Based on current understanding of climate-carbon cycle feedback, model studies suggest that to stabilise at 450 ppm carbon dioxide could require that cumulative emissions over the 21st century be reduced from an average of approximately 670 [630 to 710] GtC (2460 [2310 to 2600] $GtCO_2$) to approximately 490 [375 to 600] GtC (1800 [1370 to 2200] $GtCO_2$). Similarly, to stabilise at 1000 ppm, this feedback could require that cumulative emissions be reduced from a model average of approximately 1415 [1340 to 1490] GtC (5190 [4910 to 5460] $GtCO_2$) to approximately 1100 [980 to 1250] GtC (4030 [3590 to 4580] $GtCO_2$). {7.3, 10.4}

- If radiative forcing were to be stabilised in 2100 at B1 or A1B levels[14] a further increase in global average temperature of about 0.5°C would still be expected, mostly by 2200. {10.7}

- If radiative forcing were to be stabilised in 2100 at A1B levels[14], thermal expansion alone would lead to 0.3 to 0.8 m of sea level rise by 2300 (relative to 1980–1999). Thermal expansion would continue for many centuries, due to the time required to transport heat into the deep ocean. {10.7}

- Contraction of the Greenland Ice Sheet is projected to continue to contribute to sea level rise after 2100. Current models suggest that ice mass losses increase with temperature more rapidly than gains due to precipitation and that the surface mass balance becomes negative at a global average warming (relative to pre-industrial values) in excess of 1.9°C to 4.6°C. If a negative surface mass balance were sustained for millennia, that would lead to virtually complete elimination of the Greenland Ice Sheet and a resulting contribution to sea level rise of about 7 m. The corresponding future temperatures in Greenland are comparable to those inferred for the last interglacial period 125,000 years ago, when palaeoclimatic information suggests reductions of polar land ice extent and 4 to 6 m of sea level rise. {6.4, 10.7}

- Dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise. Understanding of these processes is limited and there is no consensus on their magnitude. {4.6, 10.7}

- Current global model studies project that the Antarctic Ice Sheet will remain too cold for widespread surface melting and is expected to gain in mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance. {10.7}

- Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the time scales required for removal of this gas from the atmosphere. {7.3, 10.3}

The Emission Scenarios of the IPCC Special Report on Emission Scenarios (SRES)[17]

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T) or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

[17] Emission scenarios are not assessed in this Working Group I Report of the IPCC. This box summarising the SRES scenarios is taken from the TAR and has been subject to prior line-by-line approval by the Panel.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

WMO

UNEP

Climate Change 2007: Impacts, Adaptation and Vulnerability

Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report

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Summary for Policymakers

This Summary for Policymakers was formally approved at the 8th Session of Working Group II of the IPCC, Brussels, April 2007

Corrections made as of 13 April 2007.
Note: text, table and figures given here are final but subject to checking and copy-editing and editorial adjustments to figures

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A. Introduction

This Summary sets out the key policy-relevant findings of the Fourth Assessment of Working Group II of the Intergovernmental Panel on Climate Change (IPCC).

The Assessment is of current scientific understanding of impacts of climate change on natural, managed and human systems, the capacity of these systems to adapt and their vulnerability[1]. It builds upon past IPCC assessments and incorporates new knowledge gained since the Third Assessment.

Statements in this Summary are based on chapters in the Assessment and principal sources are given at the end of each paragraph[2].

B. Current knowledge about observed impacts of climate change on the natural and human environment

A full consideration of observed climate change is provided in the Working Group I Fourth Assessment. This part of the Working Group II Summary concerns the relationship between observed climate change and recent observed changes in the natural and human environment.

The statements presented here are based largely on data sets that cover the period since 1970. The number of studies of observed trends in the physical and biological environment and their relationship to regional climate changes has increased greatly since the Third Assessment in 2001. The quality of the data sets has also improved. There is, however, a notable lack of geographic balance in data and literature on observed changes, with marked scarcity in developing countries.

Recent studies have allowed a broader and more confident assessment of the relationship between observed warming and impacts than was made in the Third Assessment. That Assessment concluded that "there is high confidence[3] that recent regional changes in temperature have had discernible impacts on many physical and biological systems".

From the current Assessment we conclude the following.

Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.

With regard to changes in snow, ice and frozen ground (including permafrost)[4], there is high confidence that natural systems are affected. Examples are:

- enlargement and increased numbers of glacial lakes [1.3];
- increasing ground instability in permafrost regions, and rock avalanches in mountain regions [1.3];
- changes in some Arctic and Antarctic ecosystems, including those in sea-ice biomes, and also predators high in the food chain [1.3, 4.4, 15.4].

[1] For definitions, see Endbox 1.
[2] Sources to statements are given in square brackets. For example, [3.3] refers to Chapter 3, Section 3. In the sourcing, F = Figure, T = Table, B = Box and ES = Executive Summary.
[3] See Endbox 2.
[4] See Working Group I Fourth Assessment.

Based on growing evidence, there is high confidence that the following effects on hydrological systems are occurring:

- increased run-off and earlier spring peak discharge in many glacier- and snow-fed rivers [1.3];
- warming of lakes and rivers in many regions, with effects on thermal structure and water quality [1.3].

There is very high confidence, based on more evidence from a wider range of species, that recent warming is strongly affecting terrestrial biological systems, including such changes as:

- earlier timing of spring events, such as leaf-unfolding, bird migration and egg-laying [1.3];
- poleward and upward shifts in ranges in plant and animal species [1.3, 8.2, 14.2].

Based on satellite observations since the early 1980s, there is high confidence that there has been a trend in many regions towards earlier 'greening'[5] of vegetation in the spring linked to longer thermal growing seasons due to recent warming [1.3, 14.2].

There is high confidence, based on substantial new evidence, that observed changes in marine and freshwater biological systems are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation [1.3]. These include:

- shifts in ranges and changes in algal, plankton and fish abundance in high-latitude oceans [1.3];
- increases in algal and zooplankton abundance in high-latitude and high-altitude lakes [1.3];
- range changes and earlier migrations of fish in rivers [1.3].

The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic with an average decrease in pH of 0.1 units [IPCC Working Group I Fourth Assessment]. However, the effects of observed ocean acidification on the marine biosphere are as yet undocumented [1.3].

A global assessment of data since 1970 has shown it is likely[6] that anthropogenic warming has had a discernible influence on many physical and biological systems.

Much more evidence has accumulated over the past five years to indicate that changes in many physical and biological systems are linked to anthropogenic warming. There are four sets of evidence which, taken together, support this conclusion:

1. The Working Group I Fourth Assessment concluded that most of the observed increase in the globally averaged temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.
2. Of the more than 29,000 observational data series[7], from 75 studies, that show significant change in many physical and biological systems, more than 89% are consistent with the direction of change expected as a response to warming (Figure SPM-1) [1.4].
3. A global synthesis of studies in this Assessment strongly demonstrates that the spatial agreement between regions of significant warming across the globe and the locations of significant observed changes in many systems consistent with warming is very unlikely to be due solely to natural variability of temperatures or natural variability of the systems (Figure SPM-1) [1.4].

[5] Measured by the Normalised Difference Vegetation Index, which is a relative measure of the amount of green vegetation in an area based on satellite images.

[6] See Endbox 2.

[7] A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (1) Ending in 1990 or later; (2) spanning a period of at least 20 years; and (3) showing a significant change in either direction, as assessed in individual studies.

4. Finally, there have been several modelling studies that have linked responses in some physical and biological systems to anthropogenic warming by comparing observed responses in these systems with modelled responses in which the natural forcings (solar activity and volcanoes) and anthropogenic forcings (greenhouse gases and aerosols) are explicitly separated. Models with combined natural and anthropogenic forcings simulate observed responses significantly better than models with natural forcing only [1.4].

Limitations and gaps prevent more complete attribution of the causes of observed system responses to anthropogenic warming. First, the available analyses are limited in the number of systems and locations considered. Second, natural temperature variability is larger at the regional than the global scale, thus affecting identification of changes due to external forcing. Finally, at the regional scale other factors (such as land-use change, pollution, and invasive species) are influential [1.4].

Nevertheless, the consistency between observed and modelled changes in several studies and the spatial agreement between significant regional warming and consistent impacts at the global scale is sufficient to conclude with high confidence that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems [1.4].

Other effects of regional climate changes on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers.

Effects of temperature increases have been documented in the following (medium confidence):

- effects on agricultural and forestry management at Northern Hemisphere higher latitudes, such as earlier spring planting of crops, and alterations in disturbance regimes of forests due to fires and pests [1.3];
- some aspects of human health, such as heat-related mortality in Europe, infectious disease vectors in some areas, and allergenic pollen in Northern Hemisphere high and mid-latitudes [1.3, 8.2, 8.ES];
- some human activities in the Arctic (e.g., hunting and travel over snow and ice) and in lower-elevation alpine areas (such as mountain sports) [1.3].

Recent climate changes and climate variations are beginning to have effects on many other natural and human systems. However, based on the published literature, the impacts have not yet become established trends. Examples include:

- Settlements in mountain regions are at enhanced risk to glacier lake outburst floods caused by melting glaciers. Governmental institutions in some places have begun to respond by building dams and drainage works [1.3].
- In the Sahelian region of Africa, warmer and drier conditions have led to a reduced length of growing season with detrimental effects on crops. In southern Africa, longer dry seasons and more uncertain rainfall are prompting adaptation measures [1.3].
- Sea-level rise and human development are together contributing to losses of coastal wetlands and mangroves and increasing damage from coastal flooding in many areas [1.3].

Changes in physical and biological systems and surface temperature 1970-2004

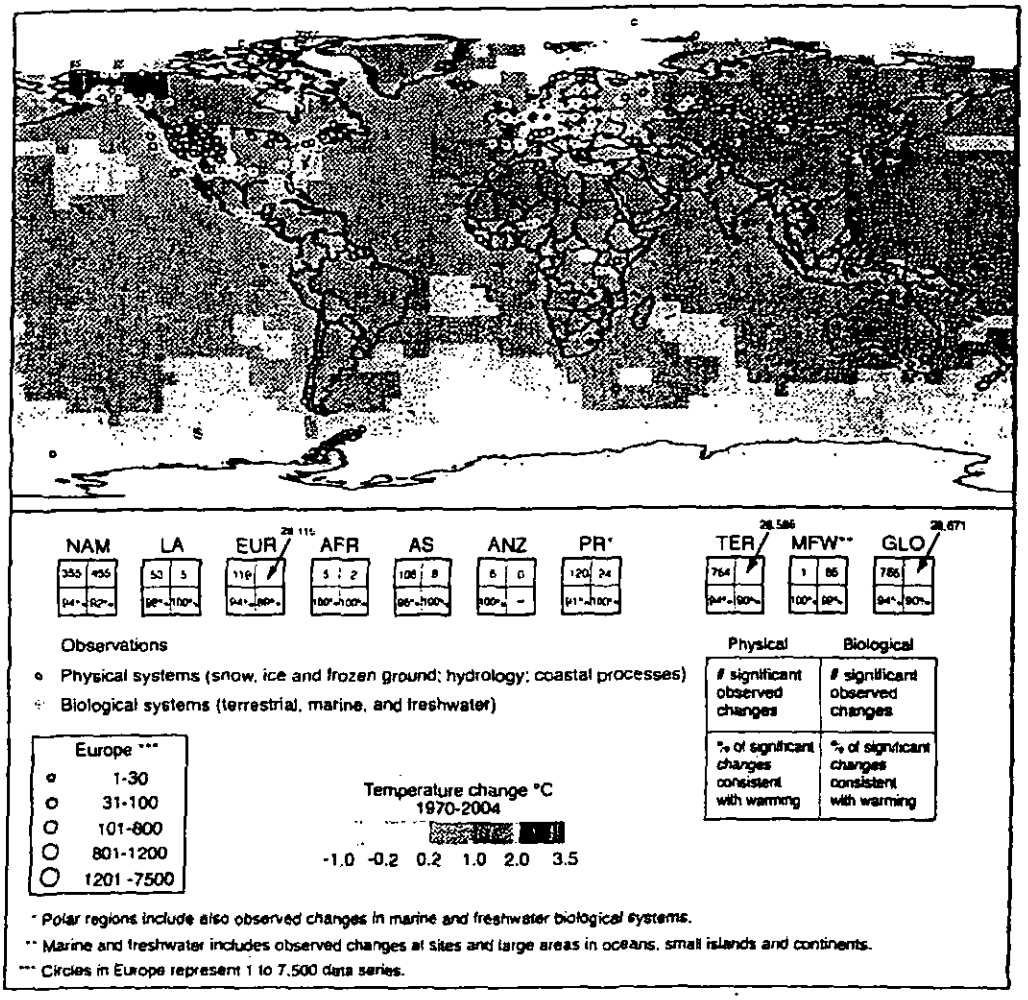

Figure SPM-1. Locations of significant changes in observations of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine, and freshwater biological systems), are shown together with surface air temperature changes over the period 1970-2004. A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (1) ending in 1990 or later; (2) spanning a period of at least 20 years; and (3) showing a significant change in either direction, as assessed in individual studies. These data series are from about 75 studies (of which ~70 are new since the Third Assessment) and contain about 29,000 data series, of which about 28,000 are from European studies. White areas do not contain sufficient observational climate data to estimate a temperature trend. The 2 x 2 boxes show the total number of data series with significant changes (top row) and the percentage of those consistent with warming (bottom row) for (i) continental regions: North America (NAM), Latin America (LA), Europe (EUR), Africa (AFR), Asia (AS), Australia and New Zealand (ANZ), and Polar Regions (PR) and (ii) global-scale: Terrestrial (TER), Marine and Freshwater (MFW), and Global (GLO). The numbers of studies from the seven regional boxes (NAM, ..., PR) do not add up to the global (GLO) totals because numbers from regions except Polar do not include the numbers related to Marine and Freshwater (MFR) systems [Working Group II Fourth Assessment F1.8, F1.9; Working Group I Fourth Assessment F3.9b].

C. Current knowledge about future impacts

The following is a selection of the key findings regarding projected impacts, as well as some findings on vulnerability and adaptation, in each system, sector and region for the range of (unmitigated) climate changes projected by the IPCC over this century[8] judged to be relevant for people and the environment[9]. The impacts frequently reflect projected changes in precipitation and other climate variables in addition to temperature, sea level and concentrations of atmospheric carbon dioxide. The magnitude and timing of impacts will vary with the amount and timing of climate change and, in some cases, the capacity to adapt. These issues are discussed further in later sections of the Summary.

More specific information is now available across a wide range of systems and sectors concerning the nature of future impacts, including for some fields not covered in previous assessments.

Fresh water resources and their management

By mid-century, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water stressed areas. In some places and in particular seasons, changes differ from these annual figures. ** D[10] [3.4]

Drought-affected areas will likely increase in extent. Heavy precipitation events, which are very likely to increase in frequency, will augment flood risk. ** N [Working Group I Fourth Assessment, Working Group II Fourth Assessment 3.4]

In the course of the century, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges, where more than one-sixth of the world population currently lives. ** N [3.4]

Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions that have recognised projected hydrological changes with related uncertainties. *** N [3.6]

Ecosystems

The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g., land use change, pollution, over-exploitation of resources). ** N [4.1 to 4.6]

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[8] Temperature changes are expressed as the difference from the period 1980-1999. To express the change relative to the period 1850-1899, add 0.5°C.

[9] Criteria of choice: magnitude and timing of impact, confidence in the assessment, representative coverage of the system, sector and region.

[10] In the Section C text, the following conventions are used:

Relationship to the Third Assessment:

D	*Further development of a conclusion in the Third Assessment*
N	*New conclusion, not in the Third Assessment*

Level of confidence in the whole statement:

***	*Very high confidence*
**	*High confidence*
*	*Medium confidence*

Over the course of this century, net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or even reverse[11], thus amplifying climate change. ** N [4.ES, F4.2]

Approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C. * N [4.4, T4.1]

For increases in global average temperature exceeding 1.5-2.5°C and in concomitant atmospheric carbon dioxide concentrations, there are projected to be major changes in ecosystem structure and function, species' ecological interactions, and species' geographic ranges, with predominantly negative consequences for biodiversity, and ecosystem goods and services e.g., water and food supply. ** N [4.4]

The progressive acidification of oceans due to increasing atmospheric carbon dioxide is expected to have negative impacts on marine shell forming organisms (e.g., corals) and their dependent species. * N [B4.4, 6.4]

Food, fibre and forest products

Crop productivity is projected to increase slightly at mid- to high latitudes for local mean temperature increases of up to 1-3°C depending on the crop, and then decrease beyond that in some regions. * D [5.4]

At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), which would increase risk of hunger. * D [5.4]

Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1-3°C, but above this it is projected to decrease. * D [5.4, 5.6]

Increases in the frequency of droughts and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes. ** D [5.4, 5.ES]

Adaptations such as altered cultivars and planting times allow low- and mid- to high-latitude cereal yields to be maintained at or above baseline yields for modest warming. * N [5.5]

Globally, commercial timber productivity rises modestly with climate change in the short- to medium-term, with large regional variability around the global trend. * D [5.4]

Regional changes in the distribution and production of particular fish species are expected due to continued warming, with adverse effects projected for aquaculture and fisheries. ** D [5.4]

Coastal systems and low-lying areas

Coasts are projected to be exposed to increasing risks, including coastal erosion, due to climate change and sea-level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas. *** D [6.3, 6.4]

Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1-3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals. *** D [B6.1, 6.4]

Coastal wetlands including salt marshes and mangroves are projected to be negatively affected by sea-

[11] Assuming continued greenhouse gas emissions at or above current rates and other global changes including land use changes

level rise especially where they are constrained on their landward side, or starved of sediment. *** D [6.4]

Many millions more people are projected to be flooded every year due to sea-level rise by the 2080s. Those densely-populated and low-lying areas where adaptive capacity is relatively low, and which already face other challenges such as tropical storms or local coastal subsidence, are especially at risk. The numbers affected will be largest in the mega-deltas of Asia and Africa while small islands are especially vulnerable. *** D [6.4]

Adaptation for coasts will be more challenging in developing countries than in developed countries, due to constraints on adaptive capacity. ** D [6.4, 6.5, T6.11]

Industry, settlement and society

Costs and benefits of climate change for industry, settlement, and society will vary widely by location and scale. In the aggregate, however, net effects will tend to be more negative the larger the change in climate. ** N [7.4, 7.6]

The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources, and those in areas prone to extreme weather events, especially where rapid urbanisation is occurring. ** D [7.1, 7.3, 7.4, 7.5]

Poor communities can be especially vulnerable, in particular those concentrated in high-risk areas. They tend to have more limited adaptive capacities, and are more dependent on climate-sensitive resources such as local water and food supplies. ** N [7.2, 7.4, 5.4]

Where extreme weather events become more intense and/or more frequent, the economic and social costs of those events will increase, and these increases will be substantial in the areas most directly affected. Climate change impacts spread from directly impacted areas and sectors to other areas and sectors through extensive and complex linkages. ** N [7.4, 7.5]

Health

Projected climate change-related exposures are likely to affect the health status of millions of people, particularly those with low adaptive capacity, through:

- increases in malnutrition and consequent disorders, with implications for child growth and development;
- increased deaths, disease and injury due to heat waves, floods, storms, fires and droughts;
- the increased burden of diarrhoeal disease;
- the increased frequency of cardio-respiratory diseases due to higher concentrations of ground level ozone related to climate change; and,
- the altered spatial distribution of some infectious disease vectors. ** D [8.4, 8.ES, 8.2]

Climate change is expected to have some mixed effects, such as the decrease or increase of the range and transmission potential of malaria in Africa. ** D [8.4]

Studies in temperate areas[12] have shown that climate change is projected to bring some benefits, such as fewer deaths from cold exposure. Overall it is expected that these benefits will be outweighed by the negative health effects of rising temperatures world-wide, especially in developing countries. ** D [8.4]

[12] Studies mainly in industrialised countries.

The balance of positive and negative health impacts will vary from one location to another, and will alter over time as temperatures continue to rise. Critically important will be factors that directly shape the health of populations such as education, health care, public health prevention and infrastructure and economic development. *** N [8.3]

More specific information is now available across the regions of the world concerning the nature of future impacts, including for some places not covered in previous assessments.

Africa

By 2020, between 75 and 250 million people are projected to be exposed to an increase of water stress due to climate change. If coupled with increased demand, this will adversely affect livelihoods and exacerbate water-related problems. ** D [9.4, 3.4, 8.2, 8.4]

Agricultural production, including access to food, in many African countries and regions is projected to be severely compromised by climate variability and change. The area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020. ** N [9.2, 9.4, 9.6]

Local food supplies are projected to be negatively affected by decreasing fisheries resources in large lakes due to rising water temperatures, which may be exacerbated by continued over-fishing. ** N [9.4, 5.4, 8.4]

Towards the end of the 21st century, projected sea-level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5-10% of Gross Domestic Product (GDP). Mangroves and coral reefs are projected to be further degraded, with additional consequences for fisheries and tourism. ** D [9.4]

New studies confirm that Africa is one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capacity. Some adaptation to current climate variability is taking place, however, this may be insufficient for future changes in climate. ** N [9.5]

Asia

Glacier melt in the Himalayas is projected to increase flooding, and rock avalanches from destabilised slopes, and to affect water resources within the next two to three decades. This will be followed by decreased river flows as the glaciers recede. * N [10.2, 10.4]

Freshwater availability in Central, South, East and Southeast Asia, particularly in large river basins, is projected to decrease due to climate change which, along with population growth and increasing demand arising from higher standards of living, could adversely affect more than a billion people by the 2050s. ** N [10.4]

Coastal areas, especially heavily-populated mega-delta regions in South, East and Southeast Asia, will be at greatest risk due to increased flooding from the sea and, in some mega-deltas, flooding from the rivers. ** D [10.4]

Climate change is projected to impinge on sustainable development of most developing countries of Asia, as it compounds the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation, and economic development. ** D [10.5]

It is projected that crop yields could increase up to 20% in East and Southeast Asia while they could decrease up to 30% in Central and South Asia by the mid-21st century. Taken together and considering the influence of rapid population growth and urbanisation, the risk of hunger is projected to remain very high in several developing countries. * N [10.4]

Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and Southeast Asia due to projected changes in the hydrological cycle associated with global warming. Increases in coastal water temperature would exacerbate the abundance and/or toxicity of cholera in South Asia. **N [10.4]

Australia and New Zealand

As a result of reduced precipitation and increased evaporation, water security problems are projected to intensify by 2030 in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions. ** D [11.4]

Significant loss of biodiversity is projected to occur by 2020 in some ecologically-rich sites including the Great Barrier Reef and Queensland Wet Tropics. Other sites at risk include Kakadu wetlands, southwest Australia, sub-Antarctic islands and the alpine areas of both countries. *** D [11.4]

Ongoing coastal development and population growth in areas such as Cairns and Southeast Queensland (Australia) and Northland to Bay of Plenty (New Zealand), are projected to exacerbate risks from sea-level rise and increases in the severity and frequency of storms and coastal flooding by 2050. *** D [11.4, 11.6]

Production from agriculture and forestry by 2030 is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits are projected in western and southern areas and close to major rivers due to a longer growing season, less frost and increased rainfall. ** N [11.4]

The region has substantial adaptive capacity due to well-developed economies and scientific and technical capabilities, but there are considerable constraints to implementation and major challenges from changes in extreme events. Natural systems have limited adaptive capacity. ** N [11.2, 11.5]

Europe

For the first time, wide ranging impacts of changes in current climate have been documented: retreating glaciers, longer growing seasons, shift of species ranges, and health impacts due to a heat wave of unprecedented magnitude. The observed changes described above are consistent with those projected for future climate change. *** N [12.2, 12.4, 12.6]

Nearly all European regions are anticipated to be negatively affected by some future impacts of climate change and these will pose challenges to many economic sectors. Climate change is expected to magnify regional differences in Europe's natural resources and assets. Negative impacts will include increased risk of inland flash floods, and more frequent coastal flooding and increased erosion (due to storminess and sea-level rise). The great majority of organisms and ecosystems will have difficulties adapting to climate change. Mountainous areas will face glacier retreat, reduced snow cover and winter tourism, and extensive species losses (in some areas up to 60% under high emission scenarios by 2080). *** D [12.4]

In Southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity. It is also projected to increase health risks due to heat waves and the frequency of wildfires. ** D [12.2, 12.4, 12.7]

In Central and Eastern Europe, summer precipitation is projected to decrease, causing higher water stress. Health risks due to heat waves are projected to increase. Forest productivity is expected to decline and the frequency of peatland fires to increase. ** D [12.4]

In Northern Europe, climate change is initially projected to bring mixed effects, including some benefits such as reduced demand for heating, increased crop yields and increased forest growth. However, as climate change continues, its negative impacts (including more frequent winter floods, endangered ecosystems and increasing ground instability) are likely to outweigh its benefits. ** D [12.4]

Adaptation to climate change is likely to benefit from experience gained in reaction to extreme climate events, by specifically implementing proactive climate change risk management adaptation plans. *** N [12.5]

Latin America

By mid-century, increases in temperature and associated decreases in soil water are projected to lead to gradual replacement of tropical forest by savanna in eastern Amazonia. Semi-arid vegetation will tend to be replaced by arid-land vegetation. There is a risk of significant biodiversity loss through species extinction in many areas of tropical Latin America ** D [13.4]

In drier areas, climate change is expected to lead to salinisation and desertification of agricultural land. Productivity of some important crops is projected to decrease and livestock productivity to decline, with adverse consequences for food security. In temperate zones soybean yields are projected to increase. ** N [13.4, 13.7]

Sea-level rise is projected to cause increased risk of flooding in low-lying areas. Increases in sea surface temperature due to climate change are projected to have adverse effects on Mesoamerican coral reefs, and cause shifts in the location of south-east Pacific fish stocks. ** N [13.4, 13.7]

Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation. ** D [13.4]

Some countries have made efforts to adapt, particularly through conservation of key ecosystems, early warning systems, risk management in agriculture, strategies for flood drought and coastal management, and disease surveillance systems. However, the effectiveness of these efforts is outweighed by: lack of basic information, observation and monitoring systems; lack of capacity building and appropriate political, institutional and technological frameworks; low income; and settlements in vulnerable areas, among others. ** D [13.2]

North America

Warming in western mountains is projected to cause decreased snowpack, more winter flooding, and reduced summer flows, exacerbating competition for over-allocated water resources. *** D [14.4, B14.2]

Disturbances from pests, diseases, and fire are projected to have increasing impacts on forests, with an extended period of high fire risk and large increases in area burned. *** N [14.4, B14.1]

Moderate climate change in the early decades of the century is projected to increase aggregate yields of rain-fed agriculture by 5-20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or depend on highly utilised water resources. ** D [14.4]

Cities that currently experience heat waves are expected to be further challenged by an increased

number, intensity and duration of heat waves during the course of the century, with potential for adverse health impacts. Elderly populations are most at risk. *** D [14.4].

Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution. Population growth and the rising value of infrastructure in coastal areas increase vulnerability to climate variability and future climate change, with losses projected to increase if the intensity of tropical storms increases. Current adaptation is uneven and readiness for increased exposure is low. *** N [14.4]

Polar Regions

In the Polar Regions, the main projected biophysical effects are reductions in thickness and extent of glaciers and ice sheets, and changes in natural ecosystems with detrimental effects on many organisms including migratory birds, mammals and higher predators. In the Arctic, additional impacts include reductions in the extent of sea ice and permafrost, increased coastal erosion, and an increase in the depth of permafrost seasonal thawing. ** D [15.3, 15.4, 15.2]

For Arctic human communities, impacts, particularly resulting from changing snow and ice conditions, are projected to be mixed. Detrimental impacts would include those on infrastructure and traditional indigenous ways of life. ** D [15.4]

Beneficial impacts would include reduced heating costs and more navigable northern sea routes. * D [15.4]

In both polar regions, specific ecosystems and habitats are projected to be vulnerable, as climatic barriers to species' invasions are lowered. ** D [15.6, 15.4]

Arctic human communities are already adapting to climate change, but both external and internal stressors challenge their adaptive capacities. Despite the resilience shown historically by Arctic indigenous communities, some traditional ways of life are being threatened and substantial investments are needed to adapt or re-locate physical structures and communities. ** D [15.ES, 15.4, 15.5, 15.7]

Small islands

Small islands, whether located in the tropics or higher latitudes, have characteristics which make them especially vulnerable to the effects of climate change, sea level rise and extreme events. *** D [16.1, 16.5]

Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources, e.g., fisheries, and reduce the value of these destinations for tourism. ** D [16.4]

Sea-level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities. *** D [16.4]

Climate change is projected by the mid-century to reduce water resources in many small islands, e.g., in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low rainfall periods. *** D [16.4]

With higher temperatures, increased invasion by non-native species is expected to occur, particularly on middle and high-latitude islands. ** N [16.4]

Magnitudes of impact can now be estimated more systematically for a range of possible increases in global average temperature.

Since the IPCC Third Assessment, many additional studies, particularly in regions that previously had been little researched, have enabled a more systematic understanding of how the timing and magnitude of impacts may be affected by changes in climate and sea level associated with differing amounts and rates of change in global average temperature.

Examples of this new information are presented in Table SPM-1. Entries have been selected which are judged to be relevant for people and the environment and for which there is high confidence in the assessment. *All entries of impact are drawn from chapters of the Assessment, where more detailed* information is available.

Depending on circumstances, some of these impacts could be associated with 'key vulnerabilities', based on a number of criteria in the literature (magnitude, timing, persistence/reversibility, the potential for adaptation, distributional aspects, likelihood and "importance" of the impacts). Assessment of potential key vulnerabilities is intended to provide information on rates and levels of climate change to help decision-makers make appropriate responses to the risks of climate change *[19.ES, 19.1]*.

The 'reasons for concern' identified in the Third Assessment remain a viable framework for considering key vulnerabilities. Recent research has updated some of the findings from the Third Assessment [19.3].

Key impacts as a function of increasing global average temperature change

(Impacts will vary by extent of adaptation, rate of temperature change, and socio-economic pathway)

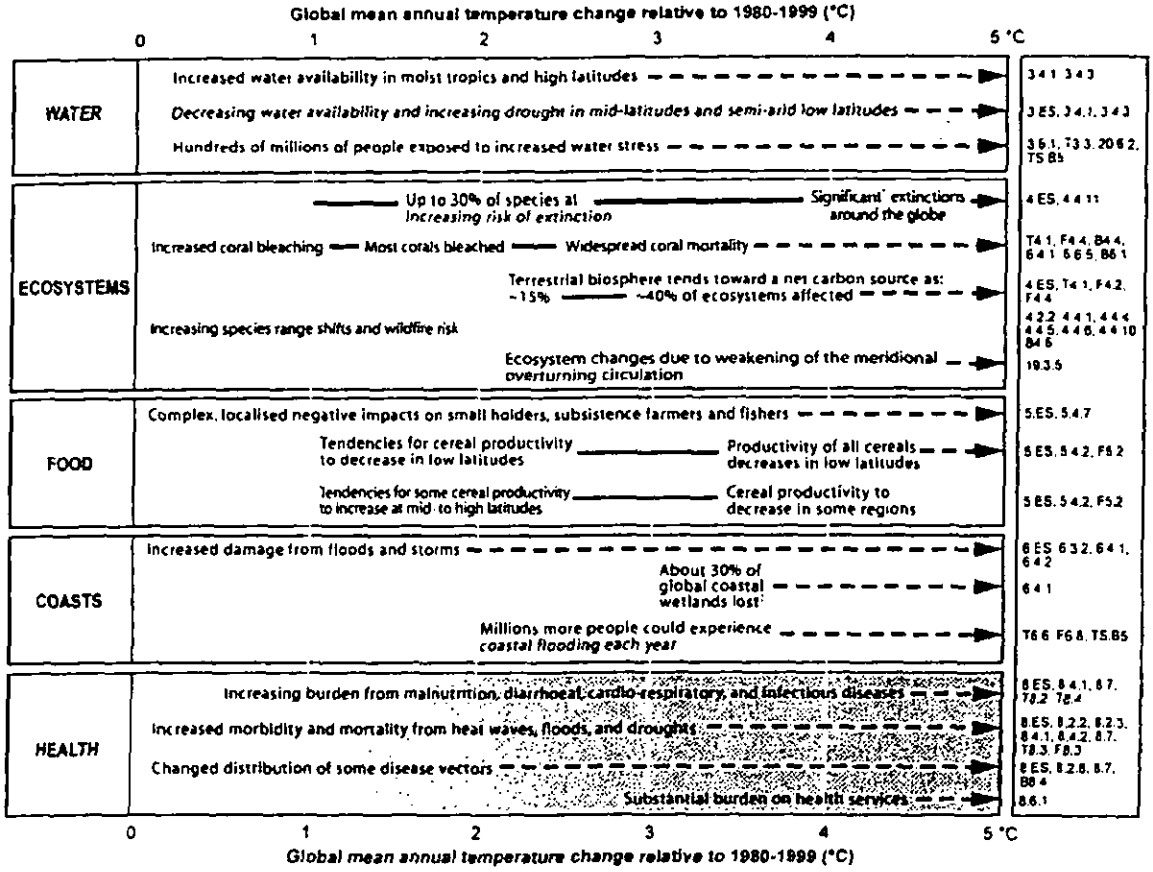

Table SPM-1. Illustrative examples of global impacts projected for climate changes (and sea-level and atmospheric carbon dioxide where relevant) associated with different amounts of increase in global average surface temperature in the 21st century [T20.7]. The black lines link impacts, dotted arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left hand side of text indicates approximate onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of Special Report on Scenarios (SRES) scenarios A1FI, A2, B1 and B2 (see Endbox 3). Adaptation to climate change is not included in these estimations. All entries are from published studies recorded in the chapters of the Assessment. Sources are given in the right hand column of the Table. Confidence levels for all statements are high.

Impacts due to altered frequencies and intensities of extreme weather, climate, and sea level events are very likely to change.

Since the IPCC Third Assessment, confidence has increased that some weather events and extremes will become more frequent, more widespread and/or more intense during the 21st century; and more is known about the potential effects of such changes. *A selection of these is presented in Table SPM-2.*

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems [4.4, 5.4]	**Water resources [3.4]**	**Human health [8.2]**	**Industry, settlement and society [7.4]**
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snow melt; effects on some water supply	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	Very likely	Reduced yields in warmer regions due to heat stress; wild fire danger increase	Increased water demand; water quality problems, e.g., algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially-isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on elderly, very young and poor.
Heavy precipitation events. Frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to water logging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries, infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	Likely	Land degradation, lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortages for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration

Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages cause disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for population migrations, loss of property
Increased *incidence* of extreme high sea level (excludes *tsunamis*)[c]	Likely[d]	Salinisation of irrigation water, estuaries and freshwater systems	Decreased freshwater availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection *versus* costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

[a] See Working Group I Fourth Assessment Table 3.7 for further details regarding definitions
[b] Warming of the most extreme days and nights each year
[c] Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
[d] In all scenarios, the projected global average sea level at 2100 is higher than in the reference period [Working Group I Fourth Assessment 10.6]. The effect of changes in regional weather systems on sea level extremes has not been assessed.

Table SPM-2. *Examples of possible impacts of climate change due to changes in extreme weather* and climate events, based on projections to the mid to late 21st century. These do not take into account any changes or developments in adaptive capacity. Examples of all entries are to be found in chapters in the full Assessment (see source at top of columns). The first two columns of this table (shaded yellow) are taken directly from the Working Group I Fourth Assessment (Table SPM-2). The likelihood estimates in Column 2 relate to the phenomena listed in Column 1. The direction of trend and likelihood of phenomena are for IPCC SRES projections of climate change.

Some large-scale climate events have the potential to cause very large impacts, *especially after the 21st century.*

Very large sea-level rises that would result from widespread deglaciation of Greenland and West Antarctic ice sheets imply major changes in coastlines and ecosystems, and inundation of low-lying areas, with greatest effects in river deltas. Relocating populations, economic activity, and infrastructure would be costly and challenging. There is medium confidence that at least partial deglaciation of the Greenland ice sheet, and possibly the West Antarctic ice sheet, would occur over a period of time ranging from centuries to millennia for a global average temperature increase of 1-4°C *(relative to 1990-2000)*, causing a contribution to sea level rise of 4-6 m or more. The complete melting of the Greenland ice sheet and the West Antarctic ice sheet would lead to a contribution to sea-level rise of up to 7 m and about 5 m, respectively [Working Group I Fourth Assessment 6.4, 10.7; *Working Group II Fourth Assessment 19.3*].

Based on climate model results, it is very unlikely that the Meridional Overturning Circulation (MOC) *in the North Atlantic will undergo a large abrupt transition during the 21st century. Slowing of the* MOC this century is very likely, but temperatures over the Atlantic and Europe are projected to increase nevertheless, due to global warming. Impacts of large-scale and persistent changes in the *MOC are likely to include changes to marine ecosystem productivity, fisheries, ocean carbon dioxide* uptake, oceanic oxygen concentrations and terrestrial vegetation [Working Group I Fourth Assessment 10.3, 10.7; Working Group II Fourth Assessment 12.6, 19.3].

Impacts of climate change will vary regionally but, aggregated and discounted to the present, they are very likely to impose net annual costs which will increase over time as global temperatures increase.

This Assessment makes it clear that the impacts of future climate change will be mixed across regions. For increases in global mean temperature of less than 1-3°C above 1990 levels, some impacts are projected to produce benefits in some places and some sectors, and produce costs in other places and other sectors. It is, however, projected that some low latitude and polar regions will experience net costs even for small increases in temperature. It is very likely that all regions will experience either declines in net benefits or increases in net costs for increases in temperature greater than about 2-3°C [9.ES, 9.5, 10.6, T109, 15.3, 15.ES]. These observations confirm evidence reported in the Third Assessment that, while developing countries are expected to experience larger percentage losses, global mean losses could be 1-5% GDP for 4°C of warming [F20.3].

Many estimates of aggregate net economic costs of damages from climate change across the globe (i.e., the social cost of carbon (SCC), expressed in terms of future net benefits and costs that are discounted to the present) are now available. Peer-reviewed estimates of the SCC for 2005 have an average value of US$43 per tonne of carbon (tC) (i.e., US$12 per tonne of carbon dioxide) but the range around this mean is large. For example, in a survey of 100 estimates, the values ran from US$-10 per tonne of carbon (US$-3 per tonne of carbon dioxide) up to US$350/tC (US$95 per tonne of carbon dioxide) [20.6].

The large ranges of SCC are due in the large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses and discount rates. It is very likely that globally-aggregated figures underestimate the damage costs because they cannot include many non-quantifiable impacts. Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time [T20.3, 20.6, F20.4].

It is virtually certain that aggregate estimates of costs mask significant differences in impacts across sectors, regions, countries, and populations. In some locations and amongst some groups of people with high exposure, high sensitivity, and/or low adaptive capacity, net costs will be significantly larger than the global aggregate [20.6, 20.ES, 7.4].

D. Current knowledge about responding to climate change

Some adaptation is occurring now, to observed and projected future climate change, but on a limited basis.

There is growing evidence since the IPCC Third Assessment of human activity to adapt to observed and anticipated climate change. For example, climate change is considered in the design of infrastructure projects such as coastal defence in the Maldives and The Netherlands, and the Confederation Bridge in Canada. Other examples include prevention of glacial lake outburst flooding in Nepal, and policies and strategies such as water management in Australia and government responses to heat waves in, for example, some European countries [7.6, 8.2, 8.6, 17.ES, 17.2, 16.5, 11.5].

Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions.

Past emissions are estimated to involve some unavoidable warming (about a further 0.6°C by the end of the century relative to 1980-1999) even if atmospheric greenhouse gas concentrations remain at 2000 levels (see Working Group I Fourth Assessment). There are some impacts for which adaptation is the only available and appropriate response. An indication of these impacts can be seen in Table SPM-1.

A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to future climate change. There are barriers, limits and costs, but these are not fully understood.

Impacts are expected to increase with increases in global average temperature, as indicated in Table SPM-1. Although many early impacts of climate change can be effectively addressed through adaptation, the options for successful adaptation diminish and the associated costs increase with increasing climate change. At present we do not have a clear picture of the limits to adaptation, or the cost, partly because effective adaptation measures are highly dependent on specific, geographical and climate risk factors as well as institutional, political and financial constraints [7.6, 17.2, 17.4].

The array of potential adaptive responses available to human societies is very large, ranging from purely technological (e.g., sea defences), through behavioural (e.g., altered food and recreational choices), to managerial (e.g., altered farm practices) and to policy (e.g., planning regulations). While most technologies and strategies are known and developed in some countries, the assessed literature does not indicate how effective various options[13] are at fully reducing risks, particularly at higher levels of warming and related impacts, and for vulnerable groups. In addition, there are formidable environmental, economic, informational, social, attitudinal and behavioural barriers to implementation of adaptation. For developing countries, availability of resources and building adaptive capacity are particularly important [see Sections 5 and 6 in Chapters 3-16; also 17.2, 17.4].

Adaptation alone is not expected to cope with all the projected effects of climate change, and especially not over the long run as most impacts increase in magnitude [Table SPM-1].

[13] A table of options is given in the Technical Summary

Vulnerability to climate change can be exacerbated by the presence of other stresses.

Non-climate stresses can increase vulnerability to climate change by reducing resilience and can also reduce adaptive capacity because of resource deployment to competing needs. For example, current stresses on some coral reefs include marine pollution and chemical runoff from agriculture as well as increases in water temperature and ocean acidification. Vulnerable regions face multiple stresses that affect their exposure and sensitivity as well as their capacity to adapt. These stresses arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict, and incidence of disease such as HIV/AIDS [7.4, 8.3, 17.3, 20.3]. Adaptation measures are seldom undertaken in response to climate change alone but can be integrated within, for example, water resource management, coastal defence, and risk reduction strategies [17.2, 17.5].

Future vulnerability depends not only on climate change but also on development pathway.

An important advance since the IPCC Third Assessment has been the completion of impacts studies for a range of different development pathways taking into account not only projected climate change but also projected social and economic changes. Most have been based on characterisations of population and income level drawn from the IPCC Special Report on Emission Scenarios (SRES) (see Endbox 3) [2.4].

These studies show that the projected impacts of climate change can vary greatly due to the development pathway assumed. For example, there may be large differences in regional population, income and technological development under alternative scenarios, which are often a strong determinant of the level of vulnerability to climate change [2.4].

To illustrate, in a number of recent studies of global impacts of climate change on food supply, risk of coastal flooding and water scarcity, the projected number of people affected is considerably greater under the A2-type scenario of development (characterised by relatively low *per capita* income and large population growth) than under other SRES futures [T20.6]. This difference is largely explained, not by differences in changes of climate, but by differences in vulnerability [T6.6].

Sustainable development[14] can reduce vulnerability to climate change, and climate change could impede nations' abilities to achieve sustainable development pathways.

Sustainable development can reduce vulnerability to climate change by enhancing adaptive capacity and increasing resilience. At present, however, few plans for promoting sustainability have explicitly included either adapting to climate change impacts, or promoting adaptive capacity [20.3].

On the other hand, it is very likely that climate change can slow the pace of progress toward sustainable development either directly through increased exposure to adverse impact or indirectly through erosion of the capacity to adapt. This point is clearly demonstrated in the sections of the sectoral and regional chapters of this report that discuss implications for sustainable development [See Section 7 in Chapters 3-8, 20.3, 20.7].

The Millennium Development Goals (MDGs) are one measure of progress towards sustainable development. Over the next half-century, climate change could impede achievement of the MDGs [20.7].

[14] The Brundtland Commission definition of sustainable development is used in this Assessment: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The same definition was used by the IPCC Working Group II Third Assessment and Synthesis Reports.

Endbox 1. Definitions of key terms

Climate change in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the Framework Convention on Climate Change, where *climate change* refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

This box of key definitions is taken from the Third Assessment and has been subject to prior line by line approval by the Panel.

Endbox 2. Communication of Uncertainty in the Working Group II Fourth Assessment

A set of terms to describe uncertainties in current knowledge is common to all parts of the IPCC Fourth Assessment.

Description of confidence

Authors have assigned a confidence level to the major statements in the Technical Summary on the basis of their assessment of current knowledge, as follows:

Terminology	*Degree of confidence in being correct*
Very high confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than a 1 out of 10 chance

Description of likelihood

Likelihood refers to a probabilistic assessment of some well defined outcome having occurred or occurring in the future, and may be based on quantitative analysis or an elicitation of expert views. In the Technical Summary, when authors evaluate the likelihood of certain outcomes, the associated meanings are:

Terminology	**Likelihood of the occurrence/ outcome**
Virtually certain	>99% probability of occurrence
Very likely	90 to 99% probability
Likely	66 to 90% probability
About as likely as not	33 to 66% probability
Unlikely	10 to 33% probability
Very unlikely	1 to 10% probability
Exceptionally unlikely	<1% probability

Endbox 3. The Emission Scenarios of the IPCC Special Report on Emission Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

This box summarizing the SRES scenarios is taken from the Third Assessment and has been subject to prior line by line approval by the Panel.

Working Group III contribution to the
Intergovernmental Panel on Climate Change
Fourth Assessment Report

Climate Change 2007: Mitigation of Climate Change

Summary for Policymakers

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This Summary for Policymakers should be cited as:
IPCC, 2007. Climate change 2007: Mitigation. Contribution of Working group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, L. A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Contents

A. Introduction

1. The Working Group III contribution to the IPCC Fourth Assessment Report (AR4) focuses on new literature on the scientific, technological, environmental, economic and social aspects of mitigation of climate change, published since the IPCC Third Assessment Report (TAR) and the Special Reports on CO_2 Capture and Storage (SRCCS) and on Safeguarding the Ozone Layer and the Global Climate System (SROC).

The following summary is organised into six sections after this introduction:

- Greenhouse gas (GHG) emission trends
- Mitigation in the short and medium term, across different economic sectors (until 2030)
- Mitigation in the long-term (beyond 2030)
- Policies, measures and instruments to mitigate climate change
- Sustainable development and climate change mitigation
- Gaps in knowledge.

References to the corresponding chapter sections are indicated at each paragraph in square brackets. An explanation of terms, acronyms and chemical symbols used in this SPM can be found in the glossary to the main report.

B. Greenhouse gas emission trends

2. Global greenhouse gas (GHG) emissions have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 *(high agreement, much evidence)*[1].

- Since pre-industrial times, increasing emissions of GHGs due to human activities have led to a marked increase in atmospheric GHG concentrations [1.3; Working Group I SPM].
- Between 1970 and 2004, global emissions of CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, weighted by their global warming potential (GWP), have increased by 70% (24% between 1990 and 2004), from 28.7 to 49 Gigatonnes of carbon dioxide equivalents ($GtCO_2$-eq)[2] (see Figure SPM.1). The emissions of these gases have increased at different rates. CO_2 emissions have grown between 1970 and 2004 by about 80% (28% between 1990 and 2004) and represented 77% of total anthropogenic GHG emissions in 2004.
- The largest growth in global GHG emissions between 1970 and 2004 has come from the energy supply sector (an increase of 145%). The growth in direct emissions[3] in this period from transport was 120%, industry 65% and land use, land use change, and forestry (LULUCF)[4] 40%[5]. Between 1970 and 1990 direct emissions from agriculture

[1] Each headline statement has an "agreement/evidence" assessment attached that is supported by the bullets underneath. This does not necessarily mean that this level of "agreement/evidence" applies to each bullet. Endbox 1 provides an explanation of this representation of uncertainty.

[2] The definition of carbon dioxide equivalent (CO_2-eq) is the amount of CO_2 emission that would cause the same radiative forcing as an emitted amount of a well mixed greenhouse gas or a mixture of well mixed greenhouse gases, all multiplied with their respective GWPs to take into account the differing times they remain in the atmosphere [WGI AR4 Glossary].

[3] Direct emissions in each sector do not include emissions from the electricity sector for the electricity consumed in the building, industry and agricultural sectors or of the emissions from refinery operations supplying fuel to the transport sector.

[4] The term "land use, land use change and forestry" is used here to describe the aggregated emissions of CO_2, CH_4, N_2O from deforestation, biomass and burning, decay of biomass from logging and deforestation, decay of peat and peat fires [1.3.1]. This is broader than emissions from deforestation, which is included as a subset. The emissions reported here do not include carbon uptake (removals).

grew by 27% and from buildings by 26%, and the latter remained at approximately at 1990 levels thereafter. However, the buildings sector has a high level of electricity use and hence the total of direct and indirect emissions in this sector is much higher (75%) than direct emissions [1.3, 6.1, 11.3, Figures 1.1 and 1.3].

- The effect on global emissions of the decrease in global energy intensity (-33%) during 1970 to 2004 has been smaller than the combined effect of global per capita income growth (77 %) and global population growth (69%); both drivers of increasing energy-related CO_2 emissions (Figure SPM.2). The long-term trend of a declining carbon intensity of energy supply reversed after 2000. Differences in terms of per capita income, per capita emissions, and energy intensity among countries remain significant. (Figure SPM.3). In 2004 UNFCCC Annex I countries held a 20% share in world population, produced 57% of world Gross Domestic Product based on Purchasing Power Parity (GDP_{ppp})[6], and accounted for 46% of global GHG emissions (Figure SPM.3a) [1.3].
- The emissions of ozone depleting substances (ODS) controlled under the Montreal Protocol[7], which are also GHGs, have declined significantly since the 1990s. By 2004 the emissions of these gases were about 20% of their 1990 level [1.3].
- A range of policies, including those on climate change, energy security[8], and sustainable development, have been effective in reducing GHG emissions in different sectors and many countries. The scale of such measures, however, has not yet been large enough to counteract the global growth in emissions [1.3, 12.2].

3. **With current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades** *(high agreement, much evidence).*
   - The SRES (non-mitigation) scenarios project an increase of baseline global GHG emissions by a range of 9.7 $GtCO_2$-eq to 36.7 $GtCO_2$-eq (25-90%) between 2000 and 2030[9] (Box SPM.1 and Figure SPM.4). In these scenarios, fossil fuels are projected to maintain their dominant position in the global energy mix to 2030 and beyond. Hence CO_2 emissions between 2000 and 2030 from energy use are projected to grow 40 to 110% over that period. Two thirds to three quarters of this increase in energy CO_2 emissions is projected to come from non-Annex I regions, with their average per capita energy CO_2 emissions being projected to remain substantially lower (2.8-5.1 tCO_2/cap) than those in Annex I regions (9.6-15.1 tCO_2/cap) by 2030. According to SRES scenarios, their economies are projected to have a lower energy use per unit of GDP (6.2 – 9.9 MJ/US$ GDP) than that of non-Annex I countries (11.0 – 21.6 MJ/US$ GDP). [1.3, 3.2]

[5] This trend is for the total LULUCF emissions, of which emissions from deforestation are a subset and, owing to large data uncertainties, is significantly less certain than for other sectors. The rate of deforestation globally was slightly lower in the 2000-2005 period than in the 1990-2000 period [9.2.1].

[6] The GDP_{ppp} metric is used for illustrative purposes only for this report. For an explanation of PPP and Market Exchange Rate (MER) GDP calculations, see footnote 12.

[7] Halons, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), methyl chloroform (CH_3CCl_3), carbon tetrachloride (CCl_4) and methyl bromide (CH_3Br).

[8] Energy security refers to security of energy supply.

[9] The SRES 2000 GHG emissions assumed here are 39.8 $GtCO_2$-eq, i.e. lower than the emissions reported in the EDGAR database for 2000 (45 $GtCO_2$-eq). This is mostly due to differences in LULUCF emissions.

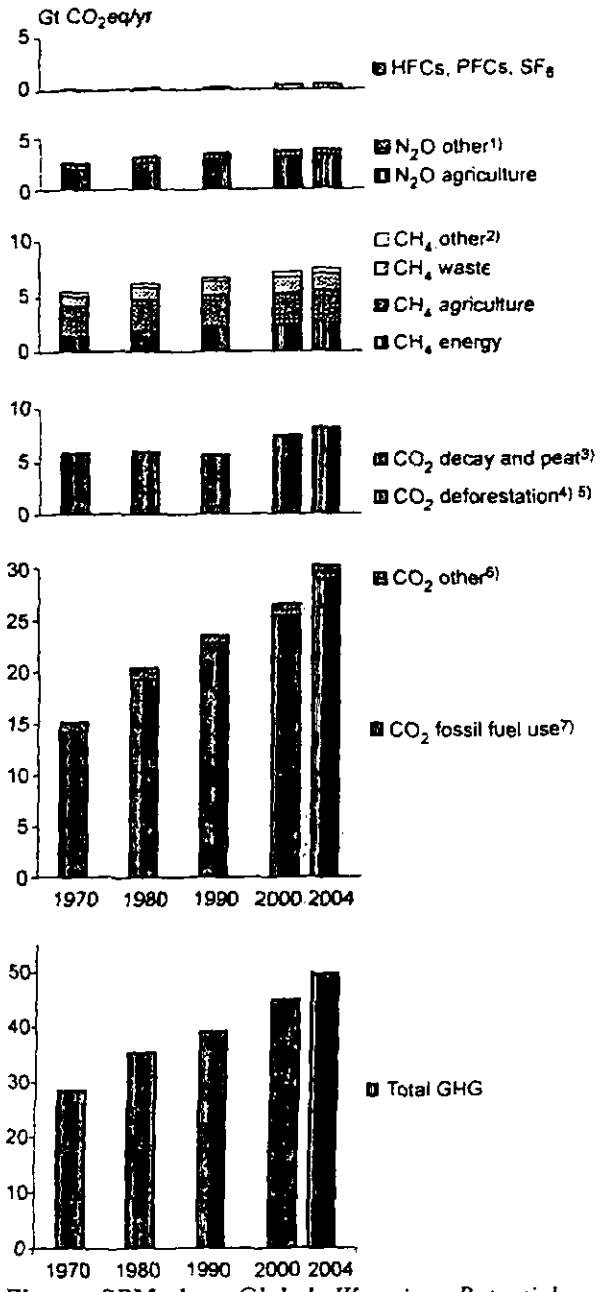


Figure SPM 1: Global Warming Potential (GWP) weighted global greenhouse gas emissions 1970-2004. 100 year GWPs from IPCC 1996 (SAR) were used to convert emissions to CO_2-eq. (cf. UNFCCC reporting guidelines). CO_2, CH_4, N_2O, HFCs, PFCs and SF_6 from all sources are included.
The two CO_2 emission categories reflect CO_2 emissions from energy production and use (second from bottom) and from land use changes (third from the bottom) [Figure 1.1a].

Notes:

1. *Other N_2O includes industrial processes, deforestation/savannah burning, waste water and waste incineration.*
2. *Other is CH_4 from industrial processes and savannah burning.*
3. *Including emissions from bioenergy production and use.*
4. *CO_2 emissions from decay (decomposition) of above ground biomass that remains after logging and deforestation and CO_2 from peat fires and decay of drained peat soils.*
5. *As well as traditional biomass use at 10% of total, assuming 90% is from sustainable biomass production. Corrected for 10% carbon of biomass that is assumed to remain as charcoal after combustion.*
6. *For large-scale forest and scrubland biomass burning averaged data for 1997-2002 based on Global Fire Emissions Data base satellite data.*
7. *Cement production and natural gas flaring.*
8. *Fossil fuel use includes emissions from feedstocks.*

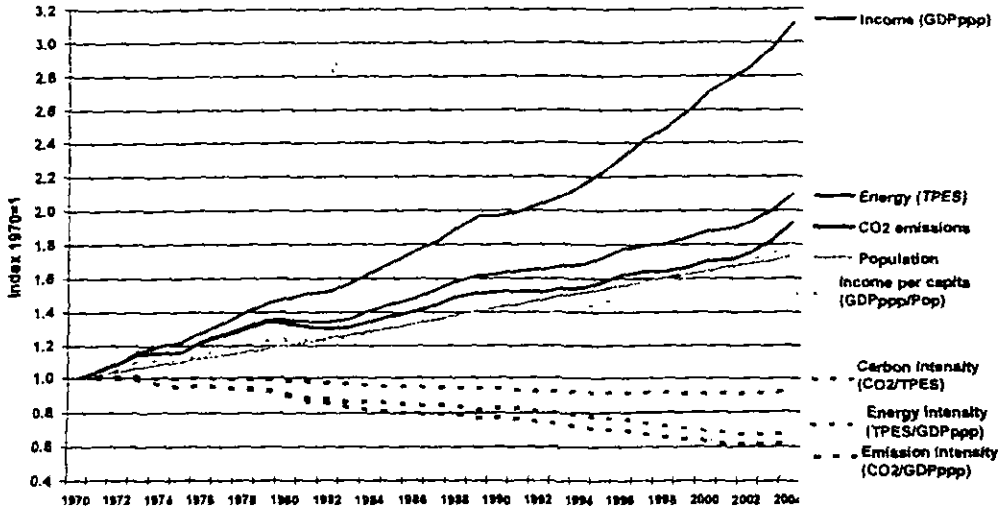


Figure SPM 2: Relative global development of Gross Domestic Product measured in PPP (GDP_{ppp}), Total Primary Energy Supply (TPES), CO_2 emissions (from fossil fuel burning, gas flaring and cement manufacturing) and Population (Pop). In addition, in dotted lines, the figure shows Income per capita (GDP_{ppp}/Pop), Energy Intensity (TPES/GDP_{ppp}), Carbon Intensity of energy supply (CO_2/TPES), and Emission Intensity of the economic production process (CO_2/GDP_{ppp}) for the period 1970-2004. [Figure 1.5]

***Figure SPM 3a**: Year 2004 distribution of regional per capita GHG emissions (all Kyoto gases, including those from land-use) over the population of different country groupings. The percentages in the bars indicate a regions share in global GHG emissions [Figure 1.4a].*

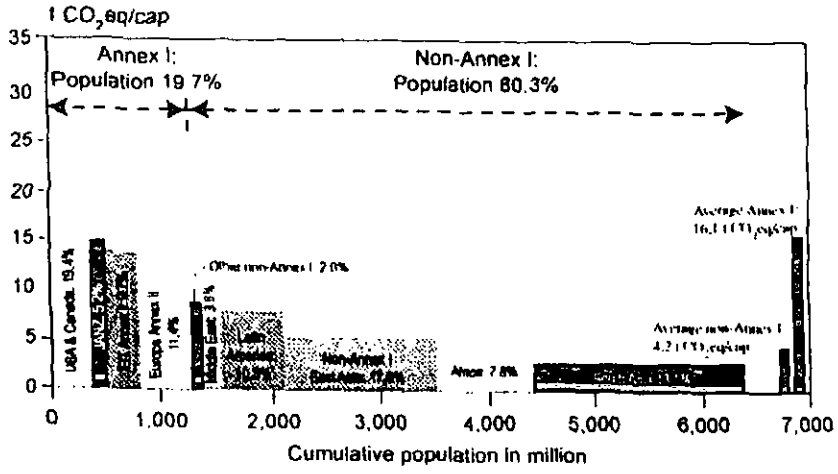
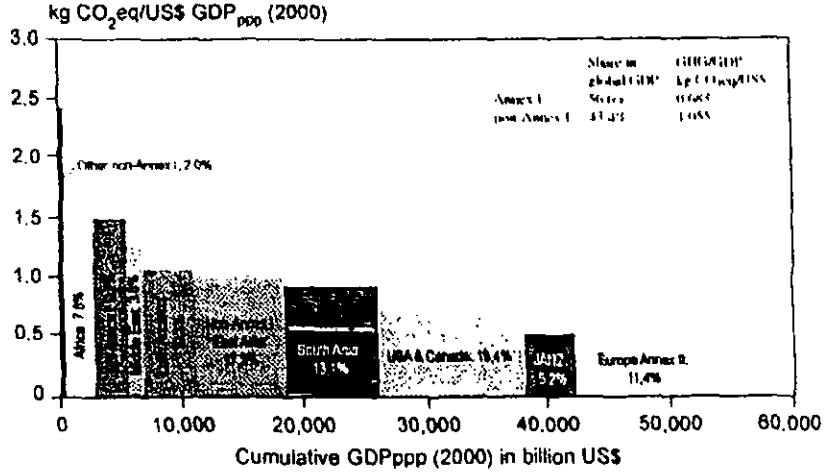


***Figure SPM 3b:** Year 2004 distribution of regional GHG emissions (all Kyoto gases, including those from land-use) per US$ of GDP_{ppp} over the GDP_{ppp} of different country groupings. The percentages in the bars indicate a regions share in global GHG emissions [Figure 1.4b].*



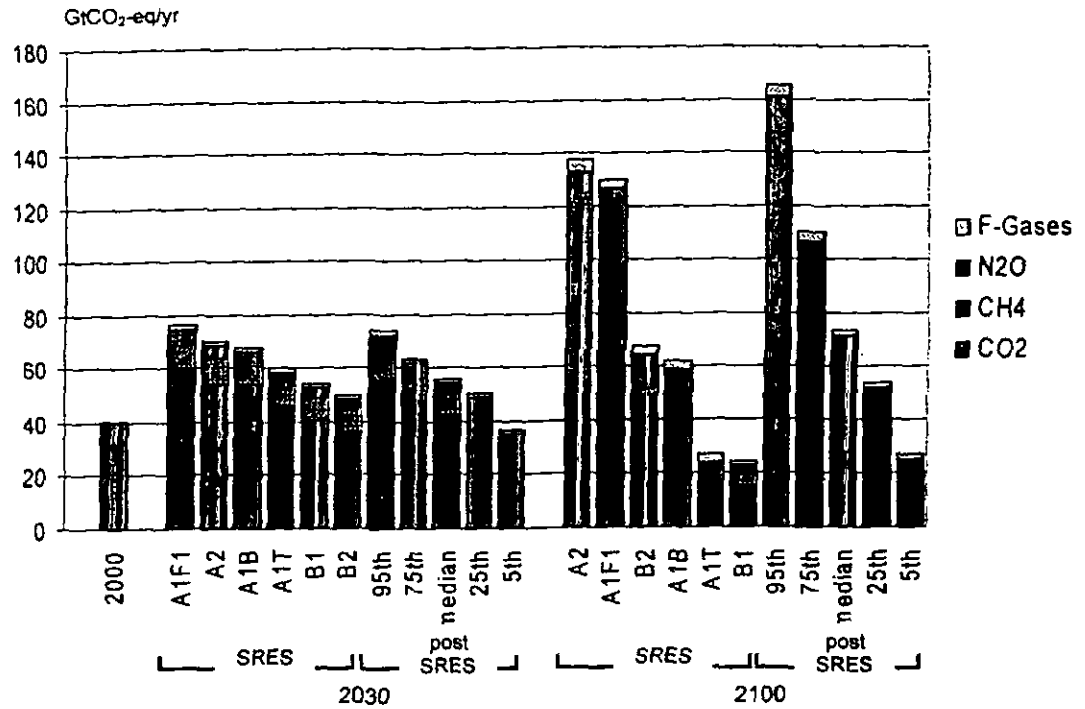


Figure SPM 4: Global GHG emissions for 2000 and projected baseline emissions[10] for 2030 and 2100 from IPCC SRES and the post-SRES literature. The figure provides the emissions from the six illustrative SRES scenarios. It also provides the frequency distribution of the emissions in the post-SRES scenarios (5th, 25th, median, 75th, 95th percentile), as covered in chapter 3. F-gases cover HFCs, PFCs and SF_6 [1.3, 3.2, Figure 1.7]. [editorial change: subscripts in legend]

4. **Baseline emissions scenarios published since SRES[10], are comparable in range to those presented in the IPCC Special Report on Emission Scenarios (SRES) (25- 135 $GtCO_2$-eq/yr in 2100, see Figure SPM.4).** *(high agreement, much evidence)*
   - Studies since SRES used lower values for some drivers for emissions, notably population projections. However, for those studies incorporating these new population projections, changes in other drivers, such as economic growth, resulted in little change in overall emission levels. Economic growth projections for Africa, Latin America and the Middle East to 2030 in post-SRES baseline scenarios are lower than in SRES, but this has only minor effects on global economic growth and overall emissions [3.2].
   - Representation of aerosol and aerosol precursor emissions, including sulphur dioxide, black carbon, and organic carbon, which have a net cooling effect[11] has improved. Generally, they are projected to be lower than reported in SRES [3.2].
   - Available studies indicate that the choice of exchange rate for GDP (MER or PPP) does not appreciably affect the projected emissions, when used consistently[12]. The differences, if any,

[10] Baseline scenarios do not include additional climate policy above current ones; more recent studies differ with respect to UNFCCC and Kyoto Protocol inclusion.

[11] See AR4 WG I report, chapter 10.2.

[12] Since TAR, there has been a debate on the use of different exchange rates in emission scenarios. Two metrics are used to compare GDP between countries. Use of MER is preferable for analyses involving internationally traded products. Use of PPP, is preferable for analyses involving comparisons of income between countries at very different stages of development. Most of the monetary units in this report are expressed in MER. This reflects the large

are small compared to the uncertainties caused by assumptions on other parameters in the scenarios, e.g. technological change [3.2].

Box SPM.1: The emission scenarios of the IPCC Special Report on Emission Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

This box summarizing the SRES scenarios is taken from the Third Assessment Report and has been subject to prior line by line approval by the Panel.

majority of emissions mitigation literature that is calibrated in MER. When monetary units are expressed in PPP, this is denoted by GDP_{ppp}.

C. Mitigation in the short and medium term (until 2030)

Box SPM 2: Mitigation potential and analytical approaches

The concept of "mitigation potential" has been developed to assess the scale of GHG reductions that could be made, relative to emission baselines, for a given level of carbon price (expressed in cost per unit of carbon dioxide equivalent emissions avoided or reduced). Mitigation potential is further differentiated in terms of "market potential" and "economic potential".

Market potential is the mitigation potential based on private costs and private discount rates[13], which might be expected to occur under forecast market conditions, including policies and measures currently in place, noting that barriers limit actual uptake [2.4].

Economic potential is the mitigation potential, which takes into account social costs and benefits and social discount rates[14], assuming that market efficiency is improved by policies and measures and barriers are removed [2.4].

Studies of market potential can be used to inform policy makers about mitigation potential with existing policies and barriers, while studies of economic potentials show what might be achieved if appropriate new and additional policies were put into place to remove barriers and include social costs and benefits. The economic potential is therefore generally greater than the market potential.

Mitigation potential is estimated using different types of approaches. There are two broad classes – "bottom-up" and "top-down" approaches, which primarily have been used to assess the economic potential.

Bottom-up studies are based on assessment of mitigation options, emphasizing specific technologies and regulations. They are typically sectoral studies taking the macro-economy as unchanged. Sector estimates have been aggregated, as in the TAR, to provide an estimate of global mitigation potential for this assessment.

Top-down studies assess the economy-wide potential of mitigation options. They use globally consistent frameworks and aggregated information about mitigation options and capture macro-economic and market feedbacks.

Bottom-up and top-down models have become more similar since the TAR as top-down models have incorporated more technological mitigation options and bottom-up models have incorporated more macroeconomic and market feedbacks as well as adopting barrier analysis into their model structures.

Bottom-up studies in particular are useful for the assessment of specific policy options at sectoral level, e.g. options for improving energy efficiency, while top-down studies are useful for assessing cross-sectoral and economy-wide climate change policies, such as carbon taxes and

[13] *Private costs and discount rates reflect the perspective of private consumers and companies; see Glossary for a fuller description.*

[14] Social costs and discount rates reflect the perspective of society. Social discount rates are lower than those used by private investors; see Glossary for a fuller description.

stabilization policies.

However, current bottom-up and top-down studies of economic potential have limitations in considering life-style choices, and in including all externalities such as local air pollution. They have limited representation of some regions, countries, sectors, gases, and barriers. The projected mitigation costs do not take into account potential benefits of avoided climate change.

Box SPM 3: Assumptions in studies on mitigation portfolios and macro-economic costs

Studies on mitigation portfolios and macro-economic costs assessed in this report are based on top-down modelling. Most models use a global least cost approach to mitigation portfolios and with universal emissions trading, assuming transparent markets, no transaction cost, and thus perfect implementation of mitigation measures throughout the 21st century. Costs are given for a specific point in time.

Global modelled costs will increase if some regions, sectors (e.g. land-use), options or gases are excluded. Global modelled costs will decrease with lower baselines, use of revenues from carbon taxes and auctioned permits, and if induced technological learning is included. These models do not consider climate benefits and generally also co-benefits of mitigation measures, or equity issues.

5. **Both bottom-up and top-down studies indicate that there is substantial economic potential for the mitigation of global GHG emissions over the coming decades, that could offset the projected growth of global emissions or reduce emissions below current levels** *(high agreement, much evidence).*

Uncertainties in the estimates are shown as ranges in the tables below to reflect the ranges of baselines, rates of technological change and other factors that are specific to the different approaches. Furthermore, uncertainties also arise from the limited information for global coverage of countries, sectors and gases.

Bottom-up studies:

- In 2030, the economic potential estimated for this assessment from bottom-up approaches (see Box SPM.2) is presented in Table SPM 1 below and Figure SPM 5A. For reference: emissions in 2000 were equal to 43 $GtCO_2$-eq. [11.3]:

Table SPM.1: Global economic mitigation potential in 2030 estimated from bottom-up studies.

Carbon price (US/tCO_2-eq)	Economic potential ($GtCO_2$-eq/yr)	Reduction relative to SRES A1 B (68 $GtCO_2$-eq/yr) (%)	Reduction relative to SRES B2 (49 $GtCO_2$-eq/yr) (%)
0	5-7	7-10	10-14
20	9-17	14-25	19-35
50	13-26	20-38	27-52
100	16-31	23-46	32-63

- Studies suggest that *mitigation opportunities with net negative costs*[15] *have the potential to* reduce emissions by around 6 $GtCO_2$-eq/yr in 2030. Realizing these requires dealing with implementation barriers [11.3].
- No one sector or technology can address the entire mitigation challenge. All assessed sectors contribute to the total (see Figure SPM 6). The key mitigation technologies and practices for the respective sectors are shown in Table SPM 3 [4.3, 4.4, 5.4, 6.5, 7.5, 8.4, 9.4, 10.4].

Top-down studies:

- Top-down studies calculate an emission reduction for 2030 as presented in Table SPM 2 below and Figure SPM 5B. The global economic potentials found in the top-down studies are in line with bottom-up studies (see Box SPM 2), though there are considerable differences at the sectoral level [3.6].

Table SPM.2: Global economic mitigation potential in 2030 estimated from top-down studies.

Carbon price (US/tCO_2-eq)	Economic potential ($GtCO_2$-eq/yr)	Reduction relative to SRES A1 B (68 $GtCO_2$-eq/yr) (%)	Reduction relative to SRES B2 (49 $GtCO_2$-eq/yr) (%)
20	9-18	13-27	18-37
50	14-23	21-34	29-47
100	17-26	25-38	35-53

- The estimates in Table SPM 2 were derived from stabilization scenarios, i.e., runs towards long-run stabilization of atmospheric GHG concentration [3.6].

[15] *In this report, as in the SAR and the TAR, options with net negative costs (no regrets opportunities) are defined as* those options whose benefits such as reduced energy costs and reduced emissions of local/regional pollutants equal or exceed their costs to society, excluding the benefits of avoided climate change (see Box SPM 1).

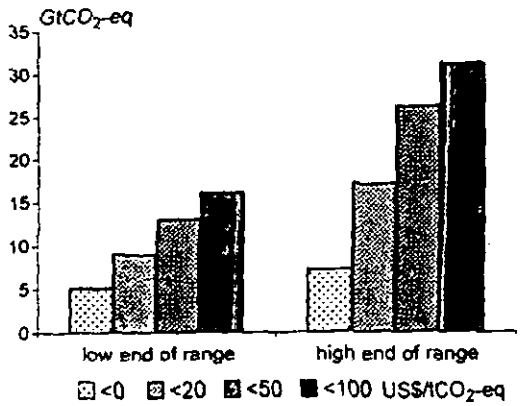


Figure SPM 5A:
Global economic mitigation potential in 2030 estimated from bottom-up studies (data from Table SPM 1)

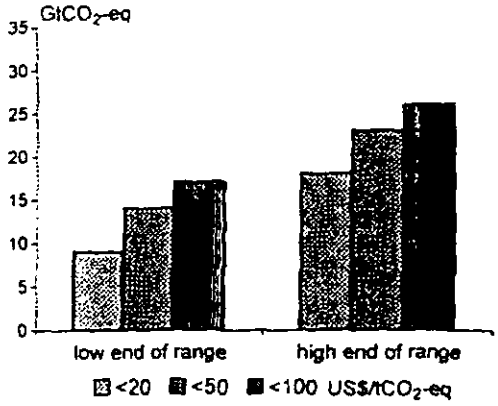
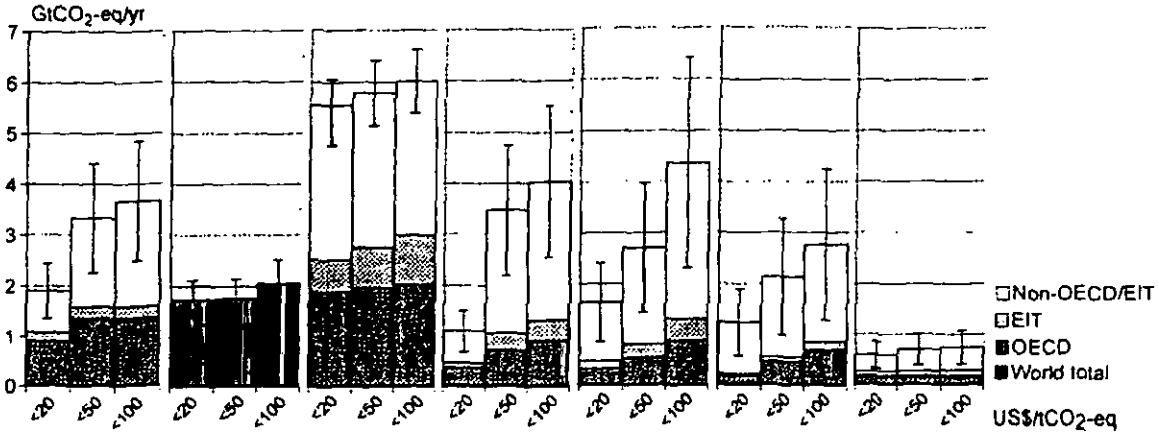


Figure SPM 5B:
Global economic mitigation potential in 2030 estimated from top-down studies (data from Table SPM 2)

Table SPM 3: *Key mitigation technologies and practices by sector. Sectors and technologies are listed in no particular order. Non-technological practices, such as lifestyle changes, which are cross-cutting, are not included in this table (but are addressed in paragraph 7 in this SPM).*

Sector	**Key mitigation technologies and practices currently commercially available.**	**Key mitigation technologies and practices projected to be commercialized before 2030.**
Energy Supply [4.3, 4.4]	Improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of CCS (e.g. storage of removed CO_2 from natural gas)	Carbon Capture and Storage (CCS) for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and waves energy, concentrating solar, and solar PV.
Transport [5.4]	More fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning	Second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries
Buildings [6.5]	Efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves, improved insulation ; passive and active solar design for heating and cooling; alternative refrigeration fluids, recovery and recycle of fluorinated gases	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; solar PV integrated in buildings
Industry [7.5]	More efficient end-use electrical equipment; heat and power recovery; material recycling and substitution; control of non-CO_2 gas emissions; and a wide array of process-specific technologies	Advanced energy efficiency; CCS for cement, ammonia, and iron manufacture; inert electrodes for aluminium manufacture
Agriculture [8.4]	Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; improved nitrogen fertilizer application techniques to reduce N_2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency	Improvements of crops yields
Forestry/forests [9.4]	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use	Tree species improvement to increase biomass productivity and carbon sequestration. Improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential and mapping land use change
Waste [10.4]	Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; recycling and waste minimization	Biocovers and biofilters to optimize CH_4 oxidation



Energy supply	Transport	Buildings	Industry	Agriculture	Forestry	Waste
(potential at <US$100/tCO2-eq: 2.4 - 4.7 Gt CO2-eq/yr)	*(potential at <US$100 /tCO2-eq: 1.6 - 2.5*	*(potential at <US$100 /tCO2-eq: 5.3 -6.7*	*(potential at <US$100/ tCO2-eq: 2.5 - 5.5*	*(potential at <US$100/t CO2-eq: 2.3 -6.4*	*(potential at <US$100 /tCO2-eq: 1.3 - 4.2*	*(potential at <US$100 /tCO2-eq: 0.4 - 1 Gt*

Figure SPM 6: *Estimated sectoral economic potential for global mitigation for different regions as a function of carbon price in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments. A full explanation of the derivation of this figure is found in 11.3.*

Notes:

1. *The ranges for global economic potentials as assessed in each sector are shown by vertical lines. The ranges are based on end-use allocations of emissions, meaning that emissions of electricity use are counted towards the end-use sectors and not to the energy supply sector.*
2. *The estimated potentials have been constrained by the availability of studies particularly at high carbon price levels.*
3. *. Sectors used different baselines. For industry the SRES B2 baseline was taken, for energy supply and transport the WEO 2004 baseline was used; the building sector is based on a baseline in between SRES B2 and A1B; for waste, SRES A1B driving forces were used to construct a waste specific baseline, agriculture and forestry used baselines that mostly used B2 driving forces.*
4. *Only global totals for transport are shown because international aviation is included [5.4].*
5. *Categories excluded are: non-CO_2 emissions in buildings and transport, part of material efficiency options, heat production and cogeneration in energy supply, heavy duty vehicles, shipping and high-occupancy passenger transport, most high-cost options for buildings, wastewater treatment, emission reduction from coal mines and gas pipelines, fluorinated gases from energy supply and transport. The underestimation of the total economic potential from these emissions is of the order of 10-15%.*

6. **In 2030 macro-economic costs for multi-gas mitigation, consistent with emissions trajectories towards stabilization between 445 and 710 ppm CO_2-eq, are estimated at between a 3% decrease of global GDP and a small increase, compared to the baseline (see Table SPM.4). However, regional costs may differ significantly from global averages** *(high agreement, medium evidence)* **(see Box SPM.3 for the methodologies and assumptions of these results).**
   - The majority of studies conclude that reduction of GDP relative to the GDP baseline increases with the stringency of the stabilization target.

***Table SPM.4**: Estimated global macro-economic costs in 2030[a] for least-cost trajectories towards different long-term stabilization levels.[b), c)]*

Stabilization levels (ppm CO_2-eq)	Median GDP reduction[d)] (%)	Range of GDP reduction[d), e)] (%)	Reduction of average annual GDP growth rates[d), f)] (percentage points)
590-710	0.2	-0.6 – 1.2	< 0.06
535-590	0.6	0.2 – 2.5	<0.1
445-535[g)]	not available	< 3	< 0.12

a) For a given stabilization level, GDP reduction would increase over time in most models after 2030. Long-term costs also become more uncertain. [Figure 3.25]
b) Results based on studies using various baselines.
c) Studies vary in terms of the point in time stabilization is achieved; generally this is in 2100 or later.
d) This is global GDP based market exchange rates.
e) The median and the 10th and 90th percentile range of the analyzed data are given.
f) The calculation of the reduction of the annual growth rate is based on the average reduction during the period till 2030 that would result in the indicated GDP decrease in 2030.
g) The number of studies that report GDP results is relatively small and they generally use low baselines.

- Depending on the existing tax system and spending of the revenues, modelling studies indicate that costs may be substantially lower under the assumption that revenues from carbon taxes or auctioned permits under an emission trading system are used to promote low-carbon technologies or reform of existing taxes [11.4].
- Studies that assume the possibility that climate change policy induces enhanced technological change also give lower costs. However, this may require higher upfront investment in order to achieve costs reductions thereafter [3.3, 3.4, 11.4, 11.5, 11.6].
- Although most models show GDP losses, some show GDP gains because they assume that baselines are non-optimal and mitigation policies improve market efficiencies, or they assume that more technological change may be induced by mitigation policies. Examples of market inefficiencies include unemployed resources, distortionary taxes and/or subsidies [3.3, 11.4].
- A multi-gas approach and inclusion of carbon sinks generally reduces costs substantially compared to CO_2 emission abatement only [3.3].
- Regional costs are largely dependent on the assumed stabilization level and baseline scenario. The allocation regime is also important, but for most countries to a lesser extent than the stabilization level [11.4, 13.3].

7. **Changes in lifestyle and behaviour patterns can contribute to climate change mitigation across all sectors. Management practices can also have a positive role.** *(high agreement, medium evidence)*
   - Lifestyle changes can reduce GHG emissions. Changes in lifestyles and consumption patterns that emphasize resource conservation can contribute to developing a low-carbon economy that is both equitable and sustainable [4.1, 6.7].
   - Education and training programmes can help overcome barriers to the market acceptance of energy efficiency, particularly in combination with other measures [Table 6.6].
   - Changes in occupant behaviour, cultural patterns and consumer choice and use of technologies can result in considerable reduction in CO_2 emissions related to energy use in buildings [6.7].
   - Transport Demand Management, which includes urban planning (that can reduce the demand for travel) and provision of information and educational techniques (that can reduce car usage and lead to an efficient driving style) can support GHG mitigation [5.1].
   - In industry, management tools that include staff training, reward systems, regular feedback, documentation of existing practices can help overcome industrial organization barriers, reduce energy use, and GHG emissions [7.3].

8. **While studies use different methodologies, in all analyzed world regions near-term health co-benefits from reduced air pollution as a result of actions to reduce GHG emissions can be substantial and may offset a substantial fraction of mitigation costs** *(high agreement, much evidence)*.
   - Including co-benefits other than health, such as increased energy security, and increased agricultural production and reduced pressure on natural ecosystems, due to decreased tropospheric ozone concentrations, would further enhance cost savings [11.8].
   - Integrating air pollution abatement and climate change mitigation policies offers potentially large cost reductions compared to treating those policies in isolation [11.8].

9. **Literature since TAR confirms that there may be effects from Annex I countries action on the global economy and global emissions, although the scale of carbon leakage remains uncertain** *(high agreement, medium evidence)*.
   - Fossil fuel exporting nations (in both Annex I and non-Annex I countries) may expect, as indicated in TAR[16], lower demand and prices and lower GDP growth due to mitigation policies. The extent of this spill over[17] depends strongly on assumptions related to policy decisions and oil market conditions [11.7].

[16] See TAR WG III (2001) SPM paragraph 16.

[17] Spill over effects of mitigation in a cross-sectoral perspective are the effects of mitigation policies and measures in one country or group of countries on sectors in other countries.

- Critical uncertainties remain in the assessment of carbon leakage[18]. Most equilibrium modelling support the conclusion in the TAR of economy-wide leakage from Kyoto action in the order of 5-20%, which would be less if competitive low-emissions technologies were effectively diffused [11.7] .

10. New energy infrastructure investments in developing countries, upgrades of energy infrastructure in industrialized countries, and policies that promote energy security, can, in many cases, create opportunities to achieve GHG emission reductions[21] compared to baseline scenarios. Additional co-benefits are country-specific but often include air pollution abatement, balance of trade improvement, provision of modern energy services to rural areas and employment *(high agreement, much evidence).*

- Future energy infrastructure investment decisions, expected to total over 20 trillion US$[19] between now and 2030, will have long term impacts on GHG emissions, because of the long life-times of energy plants and other infrastructure capital stock. The widespread diffusion of low-carbon technologies may take many decades, even if early investments in these technologies are made attractive. Initial estimates show that returning global energy-related CO_2 emissions to 2005 levels by 2030 would require a large shift in the pattern of investment, although the net additional investment required ranges from negligible to 5-10% [4.1, 4.4, 11.6].
- It is often more cost-effective to invest in end-use energy efficiency improvement than in increasing energy supply to satisfy demand for energy services. Efficiency improvement has a positive effect on energy security, local and regional air pollution abatement, and employment [4.2, 4.3, 6.5, 7.7, 11.3, 11.8].
- Renewable energy generally has a positive effect on energy security, employment and on air quality. Given costs relative to other supply options, renewable electricity, which accounted for 18% of the electricity supply in 2005, can have a 30-35% share of the total electricity supply in 2030 at carbon prices up to 50 US$/t$CO_2$-eq [4.3, 4.4, 11.3, 11.6, 11.8].
- The higher the market prices of fossil fuels, the more low-carbon alternatives will be competitive, although price volatility will be a disincentive for investors. Higher priced conventional oil resources, on the other hand, may be replaced by high carbon alternatives such as from oil sands, oil shales, heavy oils, and synthetic fuels from coal and gas, leading to increasing GHG emissions, unless production plants are equipped with CCS [4.2, 4.3, 4.4, 4.5].
- Given costs relative to other supply options, nuclear power, which accounted for 16% of the electricity supply in 2005, can have an 18% share of the total electricity supply in 2030 at carbon prices up to 50 US$/t$CO_2$-eq, but safety, weapons proliferation and waste remain as constraints [4.2, 4.3, 4.4][20].

[18] Carbon leakage is defined as the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the reduction in the emissions of these countries.

[19] 20 trillion = 20000 billion= $20*10^{12}$.

[20] Austria could not agree with this statement.

- CCS in underground geological formations is a new technology with the potential to make an important contribution to mitigation by 2030. Technical, economic and regulatory developments will affect the actual contribution [4.3, 4.4, 7.3].

11. There are multiple mitigation options in the transport sector[21], but their effect may be counteracted by growth in the sector. Mitigation options are faced with many barriers, such as consumer preferences and lack of policy frameworks *(medium agreement, medium evidence).*

- Improved vehicle efficiency measures, leading to fuel savings, in many cases have net benefits (at least for light-duty vehicles), but the market potential is much lower than the economic potential due to the influence of other consumer considerations, such as performance and size. There is not enough information to assess the mitigation potential for heavy-duty vehicles. Market forces alone, including rising fuel costs, are therefore not expected to lead to significant emission reductions [5.3, 5.4].
- Biofuels might play an important role in addressing GHG emissions in the transport sector, depending on their production pathway. Biofuels used as gasoline and diesel fuel additives/substitutes are projected to grow to 3% of total transport energy demand in the baseline in 2030. This could increase to about 5-10%, depending on future oil and carbon prices, improvements in vehicle efficiency and the success of technologies to utilise cellulose biomass [5.3, 5.4].
- Modal shifts from road to rail and to inland and coastal shipping and from low-occupancy to high-occupancy passenger transportation[22], as well as land-use, urban planning and non-motorized transport offer opportunities for GHG mitigation, depending on local conditions and policies [5.3, 5.5].
- Medium term mitigation potential for CO_2 emissions from the aviation sector can come from improved fuel efficiency, which can be achieved through a variety of means, including technology, operations and air traffic management. However, such improvements are expected to only partially offset the growth of aviation emissions. Total mitigation potential in the sector would also need to account for non-CO_2 climate impacts of aviation emissions [5.3, 5.4].
- Realizing emissions reductions in the transport sector is often a co-benefit of addressing traffic congestion, air quality and energy security [5.5].

12. Energy efficiency options[21] for new and existing buildings could considerably reduce CO_2 emissions with net economic benefit. Many barriers exist against tapping this potential, but there are also large co-benefits *(high agreement, much evidence).*

- By 2030, about 30% of the projected GHG emissions in the building sector can be avoided with net economic benefit [6.4, 6.5].

[21] See Table SPM.1 and Figure SPM.6.
[22] Including rail, road and marine mass transit and carpooling.

- Energy efficient buildings, while limiting the growth of CO_2 emissions, can also improve indoor and outdoor air quality, improve social welfare and enhance energy security [6.6, 6.7].
- Opportunities for realising GHG reductions in the building sector exist worldwide. However, multiple barriers make it difficult to realise this potential. These barriers include availability of technology, financing, poverty, higher costs of reliable information, limitations inherent in building designs and an appropriate portfolio of policies and programs [6.7, 6.8].
- The magnitude of the above barriers is higher in the developing countries and this makes it more difficult for them to achieve the GHG reduction potential of the building sector [6.7].

13. **The economic potential in the industrial sector[21] is predominantly located in energy intensive industries. Full use of available mitigation options is not being made in either industrialized or developing nations** (*high agreement, much evidence*).
    - Many industrial facilities in developing countries are new and include the latest technology with the lowest specific emissions. However, many older, inefficient facilities remain in both industrialized and developing countries. Upgrading these facilities can deliver significant emission reductions [7.1, 7.3, 7.4].
    - The slow rate of capital stock turnover, lack of financial and technical resources, and limitations in the ability of firms, particularly small and medium-sized enterprises, to access and absorb technological information are key barriers to full use of available mitigation options [7.6].

14. **Agricultural practices collectively can make a significant contribution at low cost[21] to increasing soil carbon sinks, to GHG emission reductions, and by contributing biomass feedstocks for energy use** *(medium agreement, medium evidence).*
    - A large proportion of the mitigation potential of agriculture (excluding bioenergy) arises from soil carbon sequestration, which has strong synergies with sustainable agriculture and generally reduces vulnerability to climate change [8.4, 8.5, 8.8].
    - Stored soil carbon may be vulnerable to loss through both land management change and climate change [8.10].
    - Considerable mitigation potential is also available from reductions in methane and nitrous oxide emissions in some agricultural systems [8.4, 8.5].
    - There is no universally applicable list of mitigation practices; practices need to be evaluated for individual agricultural systems and settings [8.4].
    - Biomass from agricultural residues and dedicated energy crops can be an important bioenergy feedstock, but its contribution to mitigation depends on demand for bioenergy from transport and energy supply, on water availability, and on requirements of land for food and fibre production. Widespread use of agricultural land for biomass production for energy may compete with other land uses and can have positive and negative environmental impacts and implications for food security [8.4, 8.8].

15. Forest-related mitigation activities can considerably reduce emissions from sources and increase CO_2 removals by sinks at low costs[23], and can be designed to create synergies with adaptation and sustainable development *(high agreement, much evidence)*[23].

- About 65% of the total mitigation potential (up to 100 US$/t$CO_2$-eq) is located in the tropics and about 50% of the total could be achieved by reducing emissions from deforestation [9.4].
- Climate change can affect the mitigation potential of the forest sector (i.e., native and planted forests) and is expected to be different for different regions and sub-regions, both in magnitude and direction [9.5].
- Forest-related mitigation options can be designed and implemented to be compatible with adaptation, and can have substantial co-benefits in terms of employment, income generation, biodiversity and watershed conservation, renewable energy supply and poverty alleviation [9.5, 9.6, 9.7].

16. Post-consumer waste[24] is a small contributor to global GHG emissions[25] (<5%), but the waste sector can positively contribute to GHG mitigation at low cost[21] and promote sustainable development *(high agreement, much evidence)*.

- Existing waste management practices can provide effective mitigation of GHG emissions from this sector: a wide range of mature, environmentally effective technologies are commercially available to mitigate emissions and provide co-benefits for improved public health and safety, soil protection and pollution prevention, and local energy supply [10.3, 10.4, 10.5].
- Waste minimization and recycling provide important indirect mitigation benefits through the conservation of energy and materials [10.4].
- Lack of local capital is a key constraint for waste and wastewater management in developing countries and countries with economies in transition. Lack of expertise on sustainable technology is also an important barrier [10.6].

17. Geo-engineering options, such as ocean fertilization to remove CO_2 directly from the atmosphere, or blocking sunlight by bringing material into the upper atmosphere, remain largely speculative and unproven, and with the risk of unknown side-effects. Reliable cost estimates for these options have not been published *(medium agreement, limited evidence)* [11.2].

[23] Tuvalu noted difficulties with the reference to "low costs" as Chapter 9, page 15 of the WG III report states that: "the cost of forest mitigation projects rise significantly when opportunity costs of land are taken into account".

[24] Industrial waste is covered in the industry sector.

[25] GHGs from waste include landfill and wastewater methane, wastewater N_2O, and CO_2 from incineration of fossil carbon.

D. Mitigation in the long term (after 2030)

18. In order to stabilize the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter. The lower the stabilization level, the more quickly this peak and decline would need to occur. Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels (see Table SPM.5, and Figure SPM. 8)[26] *(high agreement, much evidence)*.

- Recent studies using multi-gas reduction have explored lower stabilization levels than reported in TAR [3.3].
- *Assessed studies contain a range of emissions profiles for achieving stabilization of GHG concentrations*[27]. Most of these studies used a least cost approach and include both early and delayed emission reductions (Figure SPM.7) [Box SPM 2]. Table SPM.5 summarizes the required emissions levels for different groups of stabilization concentrations and the associated equilibrium global mean temperature increase[28], *using the 'best estimate' of climate sensitivity (see also Figure SPM.8 for the likely* range of uncertainty)[29]. Stabilization at lower concentration and related equilibrium temperature levels advances the date when emissions need to peak, and requires greater emissions reductions by 2050 [3.3].

[26] Paragraph 2 addresses historical GHG emissions since pre-industrial times.
[27] Studies vary in terms of the point in time stabilization is achieved: generally this is around 2100 or later.
[28] The information on global mean temperature is taken from the AR4 WGI report, chapter 10.8. These temperatures are reached well after concentrations are stabilized.
[29] The equilibrium climate sensitivity is a measure of the climate system response to sustained radiative forcing. It is not a projection but is defined as the global average surface warming following a doubling of carbon dioxide concentrations [AR4 WGI SPM].

***Table SPM.5**: Characteristics of post-TAR stabilization scenarios [Table TS 2, 3.10][a)]*

Category	Radiative Forcing (W/m²)[2)]	CO_2 Concentration[c)] (ppm)	CO_2-eq Concentration[c)] (ppm)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity[b), c)] (°C)	Peaking year for CO_2 emissions[d)] (year)	Change in global CO_2 emissions in 2050 (% of 2000 emissions)[d)] (%)	No. of assessed scenarios
I	2.5 – 3.0	350 – 400	445 – 490	2.0 – 2.4	2000 - 2015	-85 to -50	6
II	3.0 – 3.5	400 – 440	490 – 535	2.4 – 2.8	2000 - 2020	-60 to -30	18
III	3.5 – 4.0	440 – 485	535 – 590	2.8 – 3.2	2010 - 2030	-30 to +5	21
IV	4.0 – 5.0	485 – 570	590 – 710	3.2 – 4.0	2020 - 2060	+10 to +60	118
V	5.0 – 6.0	570 – 660	710 – 855	4.0 – 4.9	2050 - 2080	+25 to +85	9
VI	6.0 – 7.5	660 – 790	855 – 1130	4.9 – 6.1	2060 - 2090	+90 to +140	5
						Total	177

a) The understanding of the climate system response to radiative forcing as well as feedbacks is assessed in detail in the AR4 WGI Report. Feedbacks between the carbon cycle and climate change affect the required mitigation for a particular stabilization level of atmospheric carbon dioxide concentration. These feedbacks are expected to increase the fraction of anthropogenic emissions that remains in the atmosphere as the climate system warms. Therefore, the emission reductions to meet a particular stabilization level reported in the mitigation studies assessed here might be underestimated.

b) The best estimate of climate sensitivity is 3°C [WG I SPM].

c) Note that global mean temperature at equilibrium is different from expected global mean temperature at the time of stabilization of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150.

d) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios.

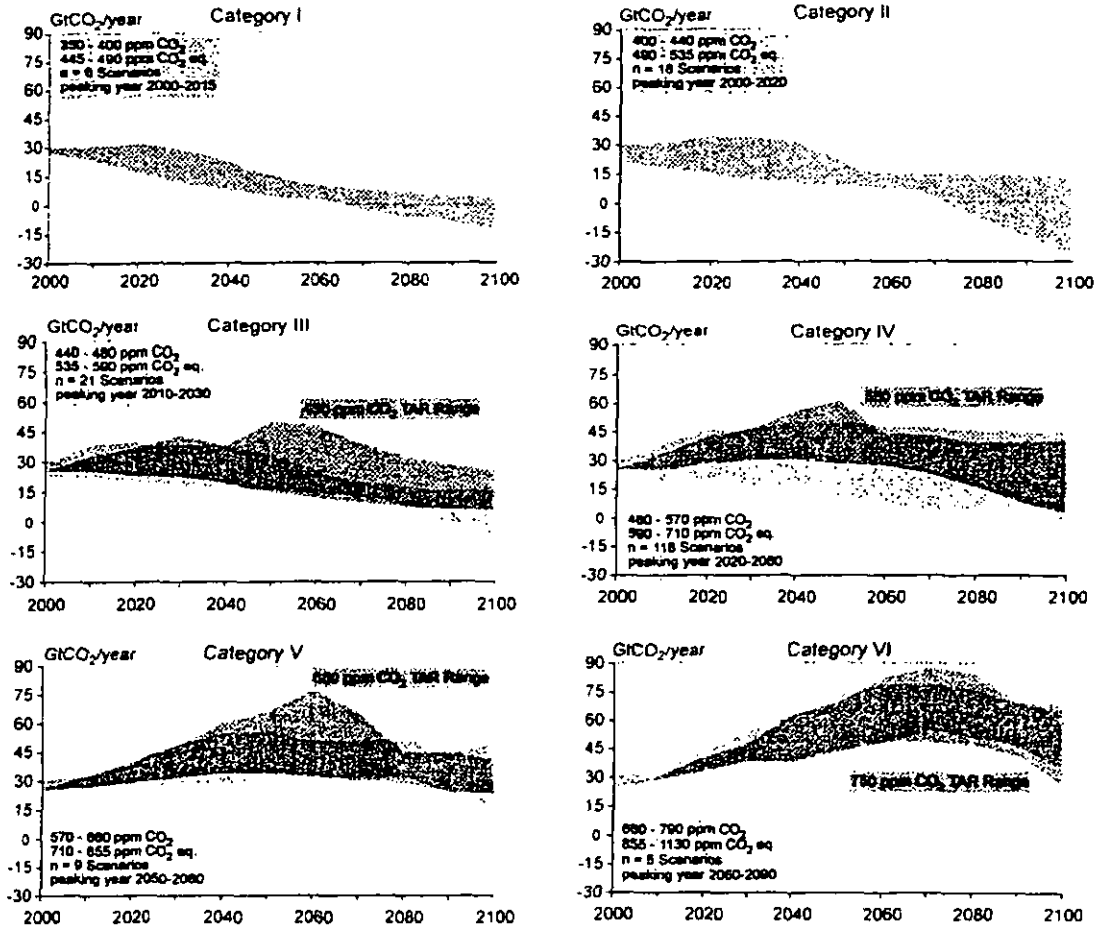


Figure SPM 7: *Emissions pathways of mitigation scenarios for alternative categories of stabilization levels (Category I to VI as defined in the box in each panel). The pathways are for CO_2 emissions only. Light brown shaded areas give the CO_2 emissions for the post-TAR emissions scenarios. Green shaded areas depict the range of more than 80 TAR stabilization scenarios. Base year emissions may differ between models due to differences in sector and industry coverage. To reach the lower stabilization levels some scenarios deploy removal of CO_2 from the atmosphere (negative emissions) using technologies such as biomass energy production utilizing carbon capture and storage. [Figure 3.17]*

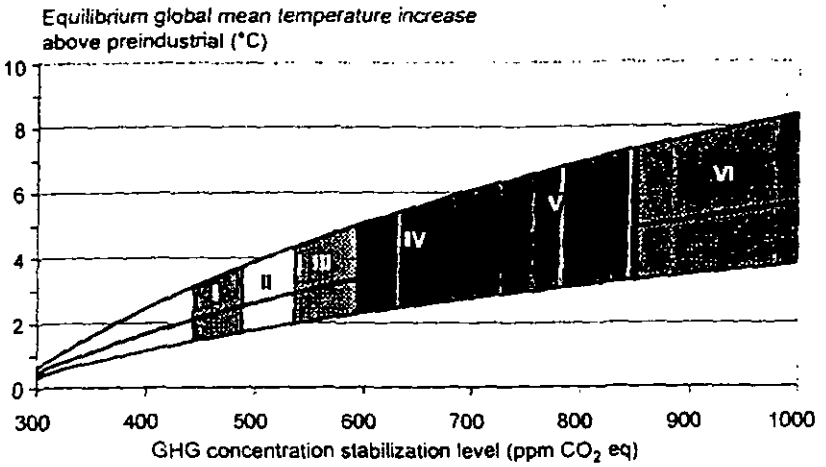


Figure SPM 8: *Stabilization scenario categories as reported in Figure SPM.7 (coloured bands) and their relationship to equilibrium global mean temperature change above pre-industrial, using (i) "best estimate" climate sensitivity of 3°C (black line in middle of shaded area), (ii) upper bound of likely range of climate sensitivity of 4.5°C (red line at top of shaded area) (iii) lower bound of likely range of climate sensitivity of 2°C (blue line at bottom of shaded area). Coloured shading shows the concentration bands for stabilization of greenhouse gases in the atmosphere corresponding to the stabilization scenario categories I to VI as indicated in Figure SPM.7. The data are drawn from AR4 WGI, Chapter 10.8.*

19. The range of stabilization levels assessed can be achieved by deployment of a portfolio of technologies that are currently available and those that are expected to be commercialised in coming decades. This assumes that appropriate and effective incentives are in place for development, acquisition, deployment and diffusion of technologies and for addressing related barriers *(high agreement, much evidence).*

- The contribution of different technologies to emission reductions required for stabilization will vary over time, region and stabilization level.
  - Energy efficiency plays a key role across many scenarios for most regions and timescales.
  - For lower stabilization levels, scenarios put more emphasis on the use of low-carbon energy sources, such as renewable energy and nuclear power, and the use of CO_2 capture and storage (CCS). In these scenarios improvements of carbon intensity of energy supply and the whole economy need to be much faster than in the past.
  - Including non-CO_2 and CO_2 land-use and forestry mitigation options provides greater flexibility and cost-effectiveness for achieving stabilization. Modern bioenergy could contribute substantially to the share of renewable energy in the mitigation portfolio.
  - For illustrative examples of portfolios of mitigation options, see figure SPM.9 [3.3, 3.4].

- Investments in and world-wide deployment of low-GHG emission technologies as well as technology improvements through public and private Research, Development & Demonstration (RD&D) would be required for achieving stabilization targets as well as cost reduction. The lower the stabilization levels, especially those of 550 ppm CO_2-eq or lower, the greater the need for more efficient RD&D efforts and investment in new technologies during the next few decades. This requires that barriers to development, acquisition, deployment and diffusion of technologies are effectively addressed.
- Appropriate incentives could address these barriers and help realize the goals across a wide portfolio of technologies. [2.7, 3.3, 3.4, 3.6, 4.3, 4.4, 4.6].

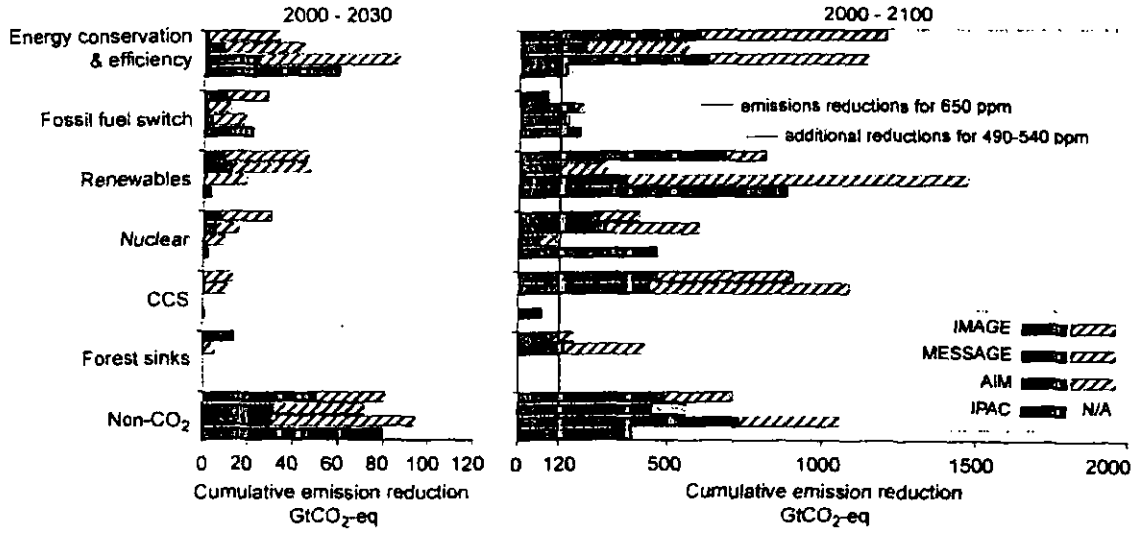


Figure SPM 9: *Cumulative emissions reductions for alternative mitigation measures for 2000 to 2030 (left-hand panel) and for 2000-2100 (right-hand panel). The figure shows illustrative scenarios from four models (AIM, IMAGE, IPAC and MESSAGE) aiming at the stabilization at 490-540 ppm CO_2-eq and levels of 650 ppm CO_2-eq, respectively. Dark bars denote reductions for a target of 650 ppm CO_2-eq and light bars the additional reductions to achieve 490-540 ppm CO_2-eq. Note that some models do not consider mitigation through forest sink enhancement (AIM and IPAC) or CCS (AIM) and that the share of low-carbon energy options in total energy supply is also determined by inclusion of these options in the baseline. CCS includes carbon capture and storage from biomass. Forest sinks include reducing emissions from deforestation. [Figure 3.23]*

20. In 2050[30] global average macro-economic costs for multi-gas mitigation towards *stabilization between* 710 *and* 445 ppm CO_2-eq, are between a 1% gain to a 5.5% decrease of global GDP (see Table SPM.6). For specific countries and sectors, costs vary considerably from the global average. (See Box SPM.3 for the methodologies and assumptions and paragraph 5 for explanation of negative costs) *(high agreement, medium evidence).*

Table SPM.6: *Estimated global macro-economic costs in 2050 relative to the baseline for least-cost trajectories towards different long-term stabilization targets[a)] [3.3, 13.3]*

Stabilization levels (ppm CO_2-eq)	Median GDP reduction[b)] (%)	Range of GDP reduction[b), c)] (%)	Reduction of average annual GDP growth rates[b), d)] (percentage points)
590-710	0.5	-1 – 2	< 0.05
535-590	1.3	slightly negative – 4	< 0.1
445- 535[e)]	not available	< 5.5	< 0.12

a) This corresponds to the full literature across all baselines and mitigation scenarios that provide GDP numbers.

b) This is global GDP based market exchange rates.

c) The median and the 10th and 90th percentile range of the analyzed data are given.

d) The calculation of the reduction of the annual growth rate is based on the average reduction during the period until 2050 that would result in the indicated GDP decrease in 2050.

e) The number of studies is relatively small and they generally use low baselines. High emissions baselines generally lead to higher costs.

21. Decision-making about the appropriate level of global mitigation over time involves an iterative risk management process that includes mitigation and adaptation, taking into account actual and avoided climate change damages, co-*benefits, sustainability, equity, and attitudes to risk.* Choices about the scale and timing of GHG mitigation involve balancing the economic costs of more rapid emission reductions now against the corresponding medium-term and long-term climate risks of delay *[high agreement, much evidence].*

- Limited and early analytical results from integrated analyses of the costs and benefits of mitigation indicate that these are broadly comparable in magnitude, but do not as yet permit an unambiguous determination of an emissions pathway or *stabilization level where benefits exceed costs [3.5].*
- Integrated assessment of the economic costs and benefits of different mitigation pathways shows that the economically optimal timing and level of mitigation depends upon the uncertain shape and character of the assumed climate change damage cost curve. To illustrate this dependency:
  - if the climate change damage cost curve grows slowly and regularly, and there is good foresight (which increases the potential for timely adaptation), *later and less stringent mitigation is economically justified;*
  - alternatively if the damage cost curve increases steeply, or contains non-linearities (e.g. vulnerability thresholds or even small probabilities of

[30] Cost estimates for 2030 are presented in paragraph 5.

catastrophic events), earlier and more stringent mitigation is economically justified [3.6].

- Climate sensitivity is a key uncertainty for mitigation scenarios that aim to meet a specific temperature level. Studies show that if climate sensitivity is high then the timing and level of mitigation is earlier and more stringent than when it is low [3.5, 3.6].
- Delayed emission reductions lead to investments that lock in more emission-intensive infrastructure and development pathways. This significantly constrains the opportunities to achieve lower stabilization levels (as shown in Table SPM.5) and increases the risk of more severe climate change impacts [3.4, 3.1, 3.5, 3.6]

Box SPM.4: *Modelling induced technological change*

Relevant literature implies that policies and measures may induce technological change. Remarkable progress has been achieved in applying approaches based on induced technological change to stabilisation studies; however, conceptual issues remain. In the models that adopt these approaches, projected costs for a given stabilization level are reduced; the reductions are greater at lower stabilisation levels.

E. Policies, measures and instruments to mitigate climate change

22. A wide variety of national policies and instruments are available to governments to create the incentives for mitigation action. Their applicability depends on national circumstances and an understanding of their interactions, but experience from implementation in various countries and sectors shows there are advantages and disadvantages for any given instrument *(high agreement, much evidence).*

- Four main criteria are used to evaluate policies and instruments: environmental effectiveness, cost effectiveness, distributional effects, including equity, and institutional feasibility [13.2].
- All instruments can be designed well or poorly, and be stringent or lax. In addition, monitoring to improve implementation is an important issue for all instruments. General findings about the performance of policies are: [7.9, 12.2,13.2]
  - *Integrating climate policies in broader development policies* makes implementation and overcoming barriers easier.
  - *Regulations and standards* generally provide some certainty about emission levels. They may be preferable to other instruments when information or other barriers prevent producers and consumers from responding to price signals. However, they may not induce innovations and more advanced technologies.
  - *Taxes and charges* can set a price for carbon, but cannot guarantee a particular level of emissions. Literature identifies taxes as an efficient way of internalizing costs of GHG emissions.

- *Tradable permits* will establish a carbon price. The volume of allowed emissions determines their environmental effectiveness, while the allocation of permits has distributional consequences. Fluctuation in the price of carbon makes it difficult to estimate the total cost of complying with emission permits.
- *Financial incentives* (subsidies and tax credits) are frequently used by governments to stimulate the development and diffusion of new technologies. While economic costs are generally higher than for the instruments listed above, they are often critical to overcome barriers.
- *Voluntary agreements* between industry and governments are politically attractive, raise awareness among stakeholders, and have played a role in the evolution of many national policies. The majority of agreements has not achieved significant emissions reductions beyond business as usual. However, some recent agreements, in a few countries, have accelerated the application of best available technology and led to measurable emission reductions.
- *Information instruments* (e.g. awareness campaigns) may positively affect environmental quality by promoting informed choices and possibly contributing to behavioural change, however, their impact on emissions has not been measured yet.
- *RD&D* can stimulate technological advances, reduce costs, and enable progress toward stabilization.

- Some corporations, local and regional authorities, NGOs and civil groups are adopting a wide variety of voluntary actions. These voluntary actions may limit GHG emissions, stimulate innovative policies, and encourage the deployment of new technologies. On their own, they generally have limited impact on the national or regional level emissions [13.4].
- Lessons learned from specific sector application of national policies and instruments are shown in Table SPM.7.

23. Policies that provide a real or implicit price of carbon could create incentives for producers and consumers to significantly invest in low-GHG products, technologies and processes. Such policies could include economic instruments, government funding and regulation (*high agreement, much evidence*).

- *An effective carbon-price signal could realize significant mitigation potential in all sectors* [11.3, 13.2].
- Modelling studies (see Box SPM.3) show carbon prices rising to 20 to 80 US$/tCO$_2$-eq by 2030 and 30 to 155 US$/tCO$_2$-eq by 2050 are consistent with stabilization at around 550 ppm CO$_2$-eq by 2100. For the same stabilization level, studies since TAR that take into account induced technological change lower these price ranges to 5 to 65 US$/tCO$_2$eq in 2030 and 15 to 130 US$/tCO$_2$-eq in 2050 [3.3, 11.4, 11.5].
- Most top-down, as well as some 2050 bottom-up assessments, suggest that real or implicit carbon prices of 20 to 50 US$/tCO$_2$-eq, sustained or increased over decades, could lead to a power generation sector with low-GHG emissions by 2050 and make many mitigation options in the end-use sectors economically attractive. [4.4,11.6]

- Barriers to the implementation of mitigation options are manifold and vary by country and sector. They can be related to financial, technological, institutional, informational and behavioural aspects [4.5, 5.5, 6.7, 7.6, 8.6, 9.6, 10.5].

5 ***Table SPM.7:*** *Selected sectoral policies, measures and instruments that have shown to be environmentally effective in the respective sector in at least a number of national cases.*

Sector	Policies[a], measures and instruments shown to be environmentally effective	Key constraints or opportunities
Energy supply [4.5]	Reduction of fossil fuel subsidies	Resistance by vested interests may make them difficult to implement
	Taxes or carbon charges on fossil fuels	
	Feed-in tariffs for renewable energy technologies	May be appropriate to create markets for low emissions technologies
	Renewable energy obligations	
	Producer subsidies	
Transport [5.5]	Mandatory fuel economy, biofuel blending and CO_2 standards for road transport	Partial coverage of vehicle fleet may limit effectiveness
	Taxes on vehicle purchase, registration, use and motor fuels, road and parking pricing	Effectiveness may drop with higher incomes
	Influence mobility needs through land use regulations, and infrastructure planning	Particularly appropriate for countries that are building up their transportation systems
	Investment in attractive public transport facilities and non-motorised forms of transport	
Buildings [6.8]	Appliance standards and labelling	Periodic revision of standards needed
	Building codes and certification	Attractive for new buildings. Enforcement can be difficult
	Demand-side management programmes	Need for regulations so that utilities may profit
	Public sector leadership programmes, including procurement	Government purchasing can expand demand for energy-efficient products
	Incentives for energy service companies (ESCOs)	Success factor: Access to third party financing
Industry [7.9]	Provision of benchmark information	May be appropriate to stimulate technology uptake. Stability of national policy important in view of international competitiveness
	Performance standards	
	Subsidies, tax credits	
	Tradable permits	Predictable allocation mechanisms and stable price signals important for investments
	Voluntary agreements	Success factors include: clear

Sector	Policies[a], measures and instruments shown to be environmentally effective	Key constraints or opportunities
		targets, a baseline scenario, *third party involvement in* design and review and formal provisions of monitoring, close cooperation between government and industry.
Agriculture [8.6, 8.7, 8.8]	Financial incentives and regulations for improved land management, maintaining soil carbon content, efficient use of fertilizers and irrigation	May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby *overcoming barriers to* implementation
Forestry/Forests [9.6]	*Financial incentives (national and* international) to increase forest area, to reduce deforestation, and to maintain and manage forests	*Constraints include lack of* investment capital and land tenure issues. Can help poverty alleviation.
	Land use regulation and enforcement	
Waste management [10.5]	Financial incentives for improved waste and wastewater management	May stimulate technology diffusion
	Renewable energy incentives or obligations	Local availability of low-cost fuel
	Waste management regulations	Most effectively applied at national level with enforcement strategies

[a] Public RD&D investment in low emission technologies have proven to be effective in all sectors.

24. *Government support through financial contributions, tax credits, standard setting and market creation is important for effective technology development, innovation and deployment. Transfer of technology to developing countries depends on enabling conditions and financing (high agreement, much evidence).*

- Public benefits of RD&D investments are bigger than the benefits captured by the private sector, justifying government support of RD&D.
- Government funding in real absolute terms for most energy research programmes has been flat or declining for nearly two decades (even after the UNFCCC came into force) and is now about half of the 1980 level [2.7, 3.4, 4.5, 11.5, 13.2].
- Governments have a crucial supportive role in providing appropriate enabling environment, such as, institutional, policy, legal and regulatory frameworks[31], to sustain investment flows and for effective technology transfer – without which it may be difficult to achieve emission reductions at a significant scale. Mobilizing

[31] See the IPCC Special Report on Methodological and Technological Issues in Technology Transfer.

financing of incremental costs of low-carbon technologies is important. International technology agreements could strengthen the knowledge infrastructure [13.3].

- The potential beneficial effect of technology transfer to developing countries brought about by Annex I countries action may be substantial, but no reliable estimates are available [11.7].
- Financial flows to developing countries through CDM projects have the potential to reach levels of the order of several billions US$ per year[32], which is higher than the flows through the Global Environment Facility (GEF), comparable to the energy oriented development assistance flows, but at least an order of magnitude lower than total foreign direct investment flows. The financial flows through CDM, GEF and development assistance for technology transfer have so far been limited and geographically unequally distributed [12.3, 13.3].

25. Notable achievements of the UNFCCC and its Kyoto protocol are the establishment of a global response to the climate problem, stimulation of an array of national policies, the creation of an international carbon market and the establishment of new institutional mechanisms that may provide the foundation for future mitigation efforts *(high agreement, much evidence).*

- The impact of the protocol's first commitment period relative to global emissions is projected to be limited. Its economic impacts on participating Annex-B countries are projected to be smaller than presented in TAR, that showed 0.2-2% lower GDP in 2012 without emissions trading, and 0.1-1.1% lower GDP with emissions trading among Annex-B countries [1.4, 11.4, 13.3].

26. The literature identifies many options for achieving reductions of global GHG emissions at the international level through cooperation. It also suggests that successful agreements are environmentally effective, cost-effective, incorporate distributional considerations and equity, and are institutionally feasible *(high agreement, much evidence).*

- Greater cooperative efforts to reduce emissions will help to reduce global costs for achieving a given level of mitigation, or will improve environmental effectiveness [13.3].
- Improving, and expanding the scope of, market mechanisms (such as emission trading, Joint Implementation and CDM) could reduce overall mitigation costs [13.3].
- Efforts to address climate change can include diverse elements such as emissions targets; sectoral, local, sub-national and regional actions; RD&D programmes; adopting common policies; implementing development oriented actions; or expanding financing instruments. These elements can be implemented in an integrated fashion, but comparing the efforts made by different countries quantitatively would be complex and resource intensive [13.3].

[32] Depends strongly on the market price that has fluctuated between 4 and 26 US$/tCO$_2$-eq and based on approximately 1000 CDM proposed plus registered projects likely to generate more than 1.3 billion emission reduction credits before 2012.

- Actions that could be taken by participating countries can be differentiated both in terms of when such action is undertaken, who participates and what the action will be. Actions can be binding or non-binding, include fixed or dynamic targets, and participation can be static or vary over time [13.3].

F. Sustainable development and climate change mitigation

27. Making development more sustainable by changing development paths can make a major contribution to climate change mitigation, but implementation may require resources to overcome multiple barriers. There is a growing understanding of the possibilities to choose and implement mitigation options in several sectors to realize synergies and avoid conflicts with other dimensions of sustainable development *(high agreement, much evidence).*

- Irrespective of the scale of mitigation measures, adaptation measures are necessary [1.2].
- Addressing climate change can be considered an integral element of sustainable development policies. National circumstances and the strengths of institutions determine how development policies impact GHG emissions. Changes in development paths emerge from the interactions of public and private decision processes involving government, business and civil society, many of which are not traditionally considered as climate policy. This process is most effective when actors participate equitably and decentralized decision making processes are coordinated [2.2, 3.3, 12.2].
- Climate change and other sustainable development policies are often but not always synergistic. There is growing evidence that decisions about macroeconomic policy, agricultural policy, multilateral development bank lending, insurance practices, electricity market reform, energy security and forest conservation, for example, which are often treated as being apart from climate policy, can significantly reduce emissions. On the other hand, decisions about improving rural access to modern energy sources for example may not have much influence on global GHG emissions [12.2].
- Climate change policies related to energy efficiency and renewable energy are often economically beneficial, improve energy security and reduce local pollutant emissions. Other energy supply mitigation options can be designed to also achieve sustainable development benefits such as avoided displacement of local populations, job creation, and health benefits [4.5,12.3].
- Reducing both loss of natural habitat and deforestation can have significant biodiversity, soil and water conservation benefits, and can be implemented in a socially and economically sustainable manner. Forestation and bioenergy plantations can lead to restoration of degraded land, manage water runoff, retain soil carbon and benefit rural economies, but could compete with land for food production and may be negative for biodiversity, if not properly designed [9.7, 12.3].

- There are also good possibilities for reinforcing sustainable development through mitigation actions in the waste management, transportation and buildings sectors [5.4, 6.6, 10.5, 12.3].
- Making development more sustainable can enhance both mitigative and adaptive capacity, and reduce emissions and vulnerability to climate change. Synergies between mitigation and adaptation can exist, for example properly designed biomass production, formation of protected areas, land management, energy use in buildings and forestry. In other situations, there may be trade-offs, such as increased GHG emissions due to increased consumption of energy related to adaptive responses [2.5, 3.5, 4.5, 6.9, 7.8, 8.5, 9.5, 11.9, 12.1].

G. Gaps in knowledge

28. There are still relevant gaps in currently available knowledge regarding some aspects of mitigation of climate change, especially in developing countries. Additional research addressing those gaps would further reduce uncertainties and thus facilitate decision-making related to mitigation of climate change [TS.14].

Endbox 1: Uncertainty representation

Uncertainty is an inherent feature of any assessment. The fourth assessment report clarifies the uncertainties associated with essential statements.

Fundamental differences between the underlying disciplinary sciences of the three Working Group reports make a common approach impractical. The "likelihood" approach applied in "Climate change 2007, the physical science basis" and the "confidence" and "likelihood" approaches used in "Climate change 2007, impacts, adaptation, and vulnerability" were judged to be inadequate to deal with the specific uncertainties involved in this mitigation report, as here human choices are considered.

In this report a two-dimensional scale is used for the treatment of uncertainty. The scale is based on the expert judgment of the authors of WGIII on the level of concurrence in the literature on a particular finding (level of agreement), and the number and quality of independent sources qualifying under the IPCC rules upon which the finding is based (amount of evidence[33]) (see Table SPM.E.1). This is not a quantitative approach, from which probabilities relating to uncertainty can be derived.

Table SPM E.1: *Qualitative definition of uncertainty*

Level of agreement (on a particular finding) ↑	Amount of evidence[a] (number and quality of independent sources) →		
High agreement, limited evidence	High agreement, medium evidence	High agreement, much evidence
Medium agreement, limited evidence	Medium agreement, medium evidence	Medium agreement, much evidence
Low agreement, limited evidence	Low agreement, medium evidence	Low agreement, much evidence

[a] *"Evidence" in this report is defined as: Information or signs indicating whether a belief or proposition is* true or valid. See Glossary.

Because the future is inherently uncertain, scenarios i.e. internally consistent images of different futures - not predictions of the future - have been used extensively in this report.

[33] "Evidence" in this report is defined as: Information or signs indicating whether a belief or proposition is true or valid. See Glossary.

Table 1. R. Hanham Testimony for PUC

Toxic Waste from Electric Utilities (Pounds), 2005

Chemical	Greene Land	Washington Land	Loudoun Land	Greene Air Emit	Washington Air Emit	Loudoun Air Emit
AMMONIA	0	0		38	1	
ARSENIC	17000	0		1400	306	
BARIUM	190000	11000		4900	1302	
CHROMIUM	35000	1700		1300	414	
COBALT	15000	0		430	0	
COPPER	43000	1800		890	160	
DIOXIN	0	0		0.00130095	0.000601965	
HYDROCHLORIC ACID	0	0		4900000	207180	
HYDROGEN FLUORIDE	0	0		430000	71960	
LEAD	16000	314		1270	513	
MANGANESE	51000	3200		1700	646	
MERCURY	58.7	1.77		454	104.9	
NICKEL	32000	0		1100	210	
SELENIUM	2900	0		10000	0	
SULFURIC ACID	0	0		790000	344199	
VANADIUM	67000	3300		2000	695	
ZINC	41000	1500		3100	1232	

Note: Land = landfills, Emit = emissions

Source: 2005 Toxic Release Inventory , EPA

Pennsylvania Public Utility Commission
Harrisburg, PA

Re: Trans-Atlantic Interstate Line Company, transmission line application

Docket Nos. a110172, a110172F0002-F0004 and G00071229

Comments of Sierra Club, Pennsylvania Chapter, Clean Air Committee

I am Nancy F. Parks, the chair of the Pennsylvania state chapter of Sierra Club's Clean Air Committee, with 24 years experience in reviewing and evaluating the status and future of the air quality of Pennsylvania in support of our more than 27,000 members.

Ground level ozone smog – it's everywhere in Pennsylvania, and it's dangerous to human health. Pennsylvania has the peculiar distinction of being both the perpetrator and the victim of air pollution. Pennsylvania has a large number of coal & other fossil fueled power plants, emitting high levels of pollution of nitrogen oxides [ozone], sulfur dioxide [acid rain], mercury [human neurotoxin], particulate matter/fine soot and carbon dioxide [global climate change], among others. These pollutants endanger the health of Pennsylvanians, and causes additional harm to our natural resources; forest mortality, soil acidification and stream acidification. Ozone smog exacerbates chronic respiratory diseases such as asthma, chronic obstructive pulmonary disease [COPD] and bronchitis, and has been more recently shown to increase mortality in cardiovascular sufferers.

The American Lung Association's State of the Air 2007 [SOA] report shows a state's report card for air pollution. They have found that pollutants from fossil fuel fired power plants continue to be a major problem for those of us currently living here in Pennsylvania. "*The most ominous trend is the increase in particle pollution, or soot, in the eastern U.S. Many areas east of the Mississippi River already had unhealthy levels of this most deadly of the widespread air pollutants. They frequently had more days and higher year-round levels of particles, here measured by PM_2*", according to SOA.. One half of Pennsylvania's 67 counties are significantly affected by particulate matter pollution, and one third of all Pennsylvania counties received a failing grade in controlling this soot which affects human health so drastically.

Mercury emissions from fossil fuel fired power plants are a recently recognized and newly regulated and controlled neurotoxin affecting Pennsylvanians as a result of bio-accumulation in food sources such as in fish. Penn State's mercury emissions report of 2005 found that "... *it is reasonable to assume that long range transport of pollutants from Ohio and western Pennsylvania sources are the major sources that were affected by the CAAA* [Clean Air Amendments of 1990*] emission reductions and are thus likely the sources also contributing to ... mercury concentrations ...* "

In spite of some improvement, control of air pollutants in Pennsylvania continues to be a major problem. At least seventeen counties in Pennsylvania are out of attainment with safer ozone smog emission limits and are now proposed for new controls and approximately one-half of Pennsylvania counties will need to comply in the near future with new fine particle soot controls.

Air pollution in Pennsylvania is all ready a major hardship for our citizens. It affects our health and costs us money to control. It is a public human health hazrd and affects our economy through damage to our natural resources.

The Sierra Club, Pennsylvania Chapter conservation policy for power plants and electricity generation demands a real & actual look at how much electricity that our citizens really need here in Pennsylvania. Energy conservation should be explored & implemented by all Pennsylvania electricity generators before there should be any consideration of new construction of power plants here in Pennsylvania. Pennsylvania is not the pollution dumping ground of those seeking new opportunities for profit through electricity generation.

All electricity generation within this state should benefit the citizens of Pennsylvania. Those benefits should be maximized energy conservation, minimized pollution emissions, maximized clean generation that is not coal fueled, and in state usage of any electricity generation that is actually needed. All electric generation must be controlled by technology to the maximum extent required by law.

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AN EVALUATION OF THE POSSIBLE RISKS FROM ELECTRIC AND MAGNETIC FIELDS (EMFS) FROM POWER LINES, INTERNAL WIRING, ELECTRICAL OCCUPATIONS, AND APPLIANCES

Prepared by
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FINAL REPORT JUNE 2002

The authors, while taking sole responsibility for their conclusions, acknowledge valuable criticism of earlier drafts of this document by the following staff of the California Department of Health Services:

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EXECUTIVE SUMMARY OF THE CALIFORNIA EMF RISK EVALUATION FOR POLICYMAKERS AND THE PUBLIC

WHY AND HOW THE EVALUATION WAS DONE:

On behalf of the California Public Utilities Commission (CPUC), three scientists who work for the California Department of Health Services (DHS) were asked to review the studies about possible health problems from electric and magnetic fields (EMFs) from power lines, wiring in buildings, some jobs, and appliances. The CPUC request for review did not include radio frequency EMFs from cell phones and radio towers. Reviewer 1, Vincent Delpizzo, Ph.D., is a physicist and epidemiologist; Reviewer 2, Raymond Richard Neutra, M.D., Dr.P.H., is a physician epidemiologist; and Reviewer 3, Geraldine Lee, Ph.D., is an epidemiologist with training in genetics. All three have published original research in the EMF area and have followed the field for many years. They were assisted in their reviews by DHS toxicologists, physicians, and epidemiologists.

THE CONCLUSIONS AFTER REVIEWING ALL THE EVIDENCE:

- *To one degree or another, all three of the DHS scientists are inclined to believe that EMFs can cause some degree of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig's Disease, and miscarriage.*
- *They strongly believe that EMFs do not increase the risk of birth defects, or low birth weight.*
- *They strongly believe that EMFs are not universal carcinogens, since there are a number of cancer types that are not associated with EMF exposure.*
- *To one degree or another they are inclined to believe that EMFs do not cause an increased risk of breast cancer, heart disease, Alzheimer's Disease, depression, or symptoms attributed by some to a sensitivity to EMFs. However,*
- *All three scientists had judgments that were "close to the dividing line between believing and not believing" that EMFs cause some degree of increased risk of suicide, or*
- *For adult leukemia, two of the scientists are "close to the dividing line between believing or not believing" and one was "prone to believe" that EMFs cause some degree of increased risk.*

HOW AND WHY THE CONCLUSIONS DIFFER FROM THOSE OF OTHER RECENT REVIEWS:

While there are important differences between the three DHS reviewers' conclusions, the DHS scientists are more inclined to believe that EMF exposure increased the risk of the above health problems than the majority of the members of scientific committees convened to evaluate the scientific literature by the National Institutes of Environmental Health Sciences Working Group (NIEHS) in 1998, the International Agency for Research on Cancer (IARC) in 2001, and the British National Radiological Protection Board (NRPB) in 2001. These other committees all assessed EMFs as a "possible" carcinogen for childhood leukemia. Thus, like the DHS panel, these other three panels were not much swayed by theoretical arguments of physicists that residential EMFs were so weak as to make any biological effect impossible. NIEHS additionally assessed EMFs as a possible carcinogen for adult lymphoid leukemia and NRPB assessed a possible link with Lou Gehrig's Disease. The three DHS scientists differed in that they had a somewhat higher degree of belief that EMF is linked with these three diseases and gave credence to evidence of a link to adult brain cancer and miscarriage that the other panels either didn't consider or characterized as "inadequate." There are several reasons for these differences. The three DHS scientists thought there were reasons why animal and test tube experiments might have failed to pick up a mechanism or a health problem; hence, the absence of much

support from such animal and test tube studies did not reduce their confidence much or lead them to strongly distrust epidemiological evidence from statistical studies in human populations. They therefore had more faith in the quality of the epidemiological studies in human populations and hence gave more credence to them.

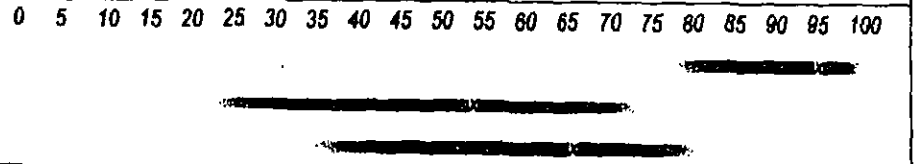
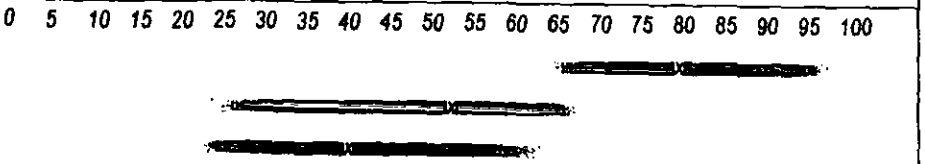
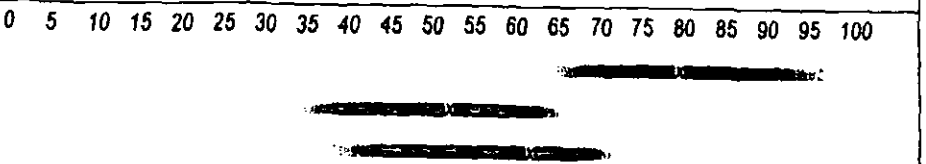
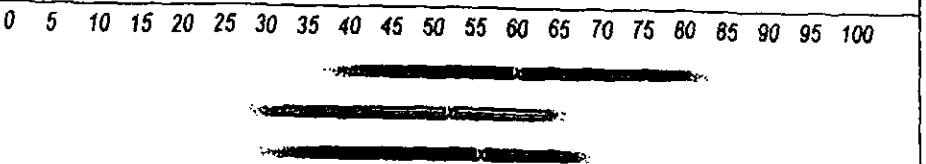
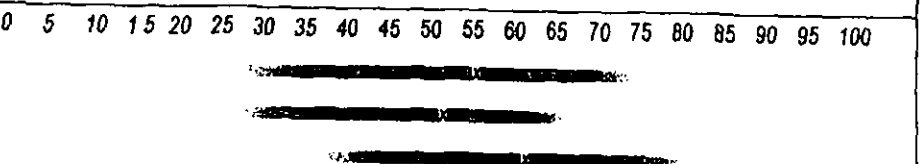
With the exception of miscarriage, which is common, the other diseases for which EMFs may be a contributing cause (childhood leukemia, adult brain cancer, Lou Gehrig's Disease) have low incidence, with rates between 1/100,000 and 1/10,000 a year. Even doubling such rates and accumulating them over a childhood or a lifetime leaves accumulated lifetime risks between 1/1,000 and 1%. Thus the vast majority (99%–99.9%) of highly exposed people would still not contract these diseases. Furthermore, calculations suggest that the fraction of all cases of the above-mentioned conditions that one could attribute to EMFs would be no more than a few percent of the total cases (if any). However, if EMFs do contribute to the cause of these conditions, even the low fractions of attributable cases and the size of accumulated lifetime risk of highly-exposed individuals could be of concern to regulators. Indeed, when deemed a real cause, estimated lifetime risks smaller than these (1/100,000) have triggered regulatory evaluation and, sometimes, actual regulation of chemical agents such as airborne benzene. The uncommon, accumulated high EMF exposures implicated by the evidence about these conditions come from unusual configurations of wiring in walls, grounded plumbing, nearby power lines, and exposure from some jobs in electrical occupations. There are ways to avoid these uncommon accumulated exposures by maintaining a distance from some appliances, changes in home wiring and plumbing, and power lines. However, to put things in perspective, individual decisions about things like buying a house or choosing a jogging route should involve the consideration of certain risks, such as those from traffic, fire, flood, and crime, as well as the uncertain comparable risks from EMFs.

While rodent and chicken egg studies provide little or no support for EMF effects, some studies on early-model higher emitting video display terminals (VDTs) and two new epidemiology studies in humans suggest that EMFs might cause a substantial proportion of miscarriages. Miscarriages are common in any case (about 10 per 100 clinically diagnosed pregnancies) and the theoretical added risk for an EMF-exposed pregnant woman might be an additional 10 per 100 pregnancies according to these two studies. If truly causal this could clearly be of concern to individuals and regulators. However, the type of EMF exposures implicated by these two new epidemiological studies (short, very high exposures) probably come from being within a few inches of appliances and unusual configurations of wiring in walls and grounded plumbing, and only rarely from power lines. Since the majority of people come into contact with non-obvious sources of these fields on a daily basis, it may not be possible to avoid the majority of such exposures in modern life, even if we avoided the obvious sources like some appliances.

Seventy-five percent of the women in the studies had at least one of these brief high exposures during a given day. Even one exposure a day, if experienced regularly during pregnancy, seemed to increase the risk of miscarriage. Nonetheless, the majority of pregnant women with such exposures did NOT miscarry.

FOR PURPOSES OF POLICY ANALYSIS, HOW DID THE THREE SCIENTISTS EXPRESS THEIR JUDGMENT THAT THE ABOVE DEGREES OF RISK MIGHT BE REAL?

The EMF Program's policy analysis required each of the three DHS scientists to express in numbers their individual professional judgments that the range of added personal risks suggested by the epidemiological studies were "real." They did this as a numerical "degree of certainty" on a scale of 0 to 100. For the conditions with the most suggestive evidence of EMF risk, the three scientists each came up with a graph that depicts their best judgments with a little "x" and the margin of uncertainty with a shaded bar. The differences in certainty between the three reviewers arises primarily from how sure they were that they could rule out study flaws or other explanatory agents and how much the evidence on one disease influenced certainty in the findings for other diseases.

CONDITION	REVIEWER	DEGREE OF CERTAINTY IN SOME AMOUNT OF ADDED PERSONAL RISK
CHILDHOOD LEUKEMIA (REVIEWED THE 19 EPIDEMIOLOGY STUDIES)	1 2 3	
ADULT LEUKEMIA (REVIEWED THE 43 EPIDEMIOLOGY STUDIES)	1 2 3	
ADULT BRAIN CANCER (REVIEWED THE 29 EPIDEMIOLOGY STUDIES)	1 2 3	
LOU GEHRIG'S DISEASE (ALS) (REVIEWED THE 7 EPIDEMIOLOGY STUDIES)	1 2 3	
MISCARRIAGE (REVIEWED THE 10 VDT, 3 ELECTRIC BLANKET, 2 PERSONAL EXPOSURE STUDIES)	1 2 3	

WHAT ASPECT OF THE "EMF MIXTURE" WOULD NEED TO BE MITIGATED (IF ANY)?

A variety of electrical phenomena are present in the vicinity of power lines, in-home wiring, plumbing, and appliances. These include EMFs with a variety of frequencies and orientations, stray currents from contact with grounded plumbing, and air pollution particles charged by electric fields. The epidemiological studies primarily implicate the magnetic fields or something closely correlated with them. Some researchers think that associated high- or low- frequency stray contact currents or charged air pollution particles are the true explanation rather than magnetic fields. The actions one would take to eliminate the fields are not always the same as one would take to eliminate the currents or the charged particles. There are some situations where different costly measures would be required to address the above-mentioned three possible explanations. There are other situations where one or more inexpensive avoidance actions will address all three. This additional uncertainty about what aspect of the mixture might need to be mitigated will thus provide a challenge for policymakers. The California EMF program funded policy projects to explore options that could be pursued in the face of these uncertainties (see www.dhs.ca.gov/ehib/emf). These are available to guide CPUC and other state agencies in policy formation. DHS is making no recommendations at this time.

WHAT RESEARCH GAPS EXIST?

Determining whether stray contact currents or charged air pollution particles are really common enough to explain the epidemiology would be highly policy relevant. Certain suggestive test tube and animal studies await replication. Epidemiology of common conditions which could be studied prospectively, like miscarriage and sudden cardiac death, would be policy relevant and could give a better understanding of what aspect of the EMF mixture might be biologically active.

OVERVIEW OF AND RATIONALE FOR THE CONCLUSIONS OF THE CALIFORNIA EMF RISK EVALUATION

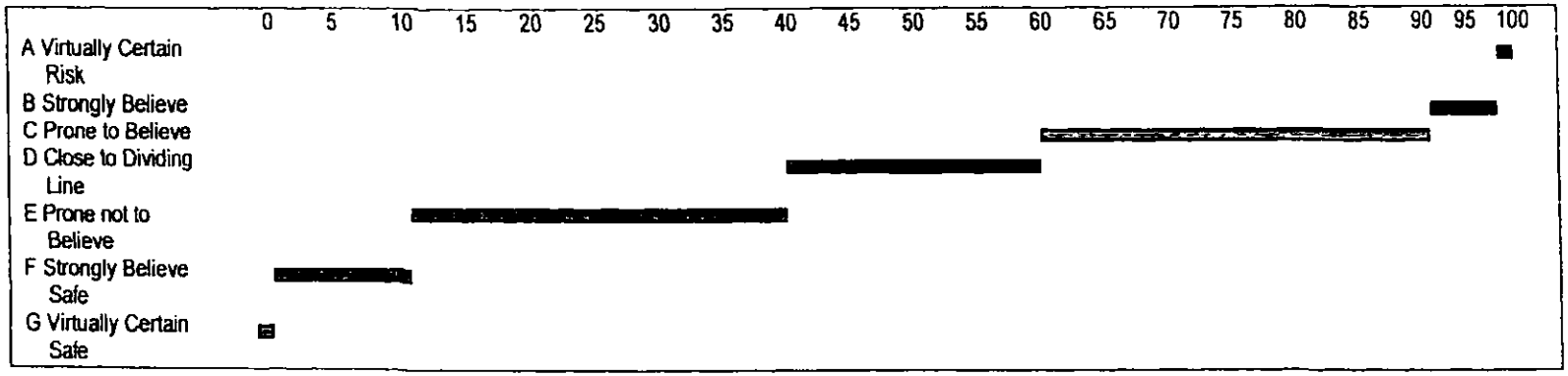
1 WHO DID THE EVALUATION AND WHAT FORM DID THE CONCLUSIONS TAKE?

On behalf of the California Public Utilities Commission (CPUC), three scientists who work for the California Department of Health Services (DHS) were asked to review the studies about possible health problems from electric and magnetic fields (EMFs) from power lines, wiring in buildings, some jobs, and appliances. The CPUC request for review did not include radio frequency EMFs from cell phones and radio towers. Reviewer 1, Vincent Delpizzo, Ph.D., is a physicist and epidemiologist; Reviewer 2, Raymond Richard Neutra, M.D., Dr.P.H., is a physician epidemiologist; and Reviewer 3, Geraldine Lee, Ph.D., is an epidemiologist with training in genetics. All three have published original research in the EMF area and have followed the field for many years. To integrate and extend their body of knowledge, the EMF Program contracted with specialists in biophysics, statistics, and animal experimentation to prepare a background in critical literature review in their respective fields and to make sure that the literature review was up to date through June 2000 (P. Gailey, Ph.D., G. Sherman, Ph.D., W. Rogers, Ph.D., and A. Martin, Ph.D.). The first three were involved with the writing of the 1998 National Institutes of Environmental Health Sciences (NIEHS) report. Furthermore, for each chapter of the review, another DHS epidemiologist or toxicologist was asked to read the original literature and consulted extensively with whichever of the three core reviewers was writing that chapter. This ensured that the writer based his/her evaluation on an understanding of the evidence that was as objective and consistent as possible. All three reviewers worked for the EMF program for at least five years and to some extent they influenced each other's thinking through their constant interaction and the review of each other's chapters. All three did their reviews according to the Risk Evaluation Guidelines (REG) that had been developed earlier and approved by the program's Science Advisory Panel (SAP). The Guidelines specified that the conclusions about any hazard should be done using two systems. The first was developed by the International Agency for Research on Cancer (IARC) and has been used by the NIEHS. It rates an agent as a Definite, Probable, Possible carcinogen or Not a carcinogen, or specifies that the evidence is "Inadequate" to rate the agent. In addition, the California Guidelines specified that in order to accommodate the probability-based computer models of the program's policy projects each of the DHS reviewers would individually assign a number between 0 and 100 to denote their degree of certainty that epidemiological associations between EMFs and certain diseases indicated that EMFs increased the risk of those diseases to some degree. They indicated their best judgement graphically with a little "x" and placed a shaded bar on either side of that "x" to indicate how *uncertain* they were. The best judgement and the uncertainty ranges could be used in quantitative policy analysis. The Guidelines, which were modified with advice from *public comment and the SAP and the DHS reviewers*, attached pre-agreed-upon English language phrases to various ranges of this degree of certainty. These are presented below in Table I.

If all three judges had best judgments above 50 out of 100, but that fell in different categories in Table I, judges were said to be "inclined to believe" that EMFs increased the risk of that disease to some degree.

TABLE I. EVERYDAY ENGLISH PHRASES TO DESCRIBE DEGREES OF CERTAINTY OF CAUSALITY (GRAPH ILLUSTRATES THE RANGE OF CERTAINTY NUMBERS TO WHICH THE PHRASES PERTAIN)

ARE THE HIGHEST EMFS AT HOME OR AT WORK SAFE, OR DO HIGH EMFS INCREASE THE RISK OF ..... TO A DEGREE DETECTABLE BY EPIDEMIOLOGY?	DEGREE OF CERTAINTY ON A SCALE OF 1 TO 100
Virtually certain that they increase the risk to some degree	>99.5
Strongly believe that they increase the risk to some degree	90 to 99.5
Prone to believe that they increase the risk to some degree	60 to 90
Close to the dividing line between believing or not believing that EMFs increase the risk to some degree	40 to 60
Prone to believe that they do not increase the risk to any degree	10 to 40
Strongly believe that they do not increase the risk to any degree	0.5 to 10
Virtually certain that they do not increase the risk to any degree	< 0.5



2 A Summary of What has Changed Since the California EMF Program Was First Proposed In the Early 1990s

Between the time CPUC mandated a targeted California research program in 1993 to the time of this writing, considerable information has accumulated. In addition, three expert panels, the NIEHS Working Group (Portier & Wolfe, 1998), the IARC (IARC, 2001), and the British National Radiological Protection Board (NRPB, 2001b) have indicated that EMFs are a possible cause of childhood leukemia.

Biophysics: Biophysical arguments based on physical principles and simplified biological models have produced lower and lower predictions as to what magnetic field intensities theoretically would be capable of producing biological effects. Nevertheless, theoretical modeling still would claim that most residential and occupational epidemiological results are "impossible" (Weaver et al., 1998). It would also claim that bioeffects from magnetic field experiments using intensities less than 100 mG* are "impossible" (Adair, 1999). A milliGauss (mG) is a commonly used measure of magnetic field strength. An average living room would have a 0.7 mG field. The standard international unit is a microTesla (μT). One μT equals 10 mG. Both units appear in this document. Those who adhere to these biophysical theories still discount the relevance of experimental results at higher intensities because of this "impossibility" threshold and would require robust bioeffect laboratory results from ambient levels of exposure. This is an unusual burden of proof since ambient levels of other pollutants often do not produce effects large enough to see in the laboratory. It should be noted that the majority of panelists at IARC, NIEHS, and NRPB who declared EMFs as "possible" carcinogens obviously did not accept some physicists arguments that bioeffects from high-end residential exposures were "impossible."

Mechanistic Research: EMFs, particularly those above 1000 mG, have been shown to have a number of physiological effects on cells (Portier & Wolfe, 1998), but the physical induction mechanisms of these effects are not clearly understood. No consensus has arisen on a mechanistic explanation of how the various epidemiological associations might have occurred. Repeated studies of the effects of pulsed and non-pulsed EMFs below 100 mG on chick embryos, in several laboratories, have continued to show "non-robust" effects (Martin, 1988), (Berman et al., 1990), (Martin, 1992), (Moses & Martin, 1992), (Moses & Martin, 1993), (Martin & Moses, 1995), (Litovitz et al., 1994), (Farrell et al., 1997a), (Farrell et al., 1997b), (Leal et al., 1989), (Chacon et al., 1990), (Ubeda et al., 1994), (Koch & Koch, 1991), (Singh & et al., 1991), (Espinar et al., 1997), (Blackman et al., 1988), (Yip et al., 1994a), (Yip et al., 1994b), (Coulton & Barker, 1991), (Youbicier-Simo et al., 1997), (Piera et al., 1992), (Pafkova & Jerabek, 1994), (Pafkova, Tejnorova & Jerabek, 1994), (Pafkova et al., 1996), (Veicsteinas et al., 1996). A statistically significant effect is said to be "non-robust" when its size is not greater than the differences between control groups in various experiments. Several independent researchers (Liburdy et al., 1993), (Blackman, Benane & House, 2001), and (Ishido, Nitta & Kabuto, 2001) have published studies on the effect of low intensity (12 mG, 60 Hertz) magnetic fields on the ability of melatonin to inhibit cancer cell proliferation in vitro. Thus, there are some studies that, while not universally accepted, purport to show biological effects at EMF intensities declared by biophysicists to be incapable of producing such effects.

Animal Pathology: A large number of animal pathology studies have been carried out that tested a few aspects of the EMF mixture and, with some exceptions, did not show a carcinogenic, reproductive, or immunological effect (Portier & Wolfe, 1998). This has led some scientists to conclude that EMFs are probably safe.

Two laboratories in the former Soviet Union (Beniashvili, Bilanishvili & Menabde, 1991), (Anisimov et al., 1996) and one in Germany (Loscher et al., 1993), (Mevissen, Lerchl & Loscher, 1996a) reported co-promotional effects of magnetic fields on the occurrence of breast tumors in rats, though this result did not recur in two experiments in the United States (Anderson et al., 1999), (Boorman et al., 1999a) that partially replicated the conditions in the German experiments.

Epidemiology: Epidemiological studies on workers and children have tentatively implicated a wider range of diseases than the leukemia and brain cancer that dominated discussion in the early 1980s and 1990s (Portier & Wolfe, 1998). Published statistical summaries of the body of epidemiological evidence have suggested that chance is an unlikely explanation for the associations seen for childhood leukemia (Greenland et al., 2000), (Ahlbom et al., 2000), adult leukemia (Kheifets et al., 1997a), adult brain cancer (Kheifets, 2001), male breast cancer (Erren, 2001), and Amyotrophic Lateral Sclerosis (Ahlbom, 2001). This leaves bias, confounding, or EMF causality as alternative explanations. (See pp 21-22 below for definitions.) Parts of this evidence have convinced the NIEHS, the IARC, and the NRPB that EMFs are a **possible** carcinogen.

For childhood leukemia, the association now seems more consistent with measured 30-300 Hz magnetic fields than with proximity to power lines (Greenland et al.,

* A milligauss (mG) is a measure of magnetic field intensity. A typical living room measures about 0.7 mG. The average exposure during the day of a typical white-collar worker would be around 1 mG, a utility worker exposed to high fields during the day might average around 7 mG, while an electric train operator's exposure might average around 100 mG.

2000). Furthermore, alternative explanations of the associations, such as traffic and social class, seem much less likely (Reynolds et al., 2001), (Langholz, 2001). The study of Linet et al. on childhood leukemia (Linet et al., 1997) was originally and prominently interpreted as showing no effect. It has now been shown to contribute important support in pooled analyses that indicate that the association between the *highest exposures to EMF and childhood leukemia are unlikely to be due to chance* (Greenland et al., 2000).

An epidemiological literature is developing that associates magnetic fields with diseases and conditions that are more common than cancer, such as sudden cardiac death, dementia, suicide (NIEHS, Portier & Wolf, 1998), and spontaneous abortion (Li et al., 2002), (Lee et al., 2002). From a cost/benefit perspective, the confirmation of the associations with these more common diseases would have greater utilitarian policy implications (Florig, 2001) than the confirmation of EMF associations with rare diseases, such as childhood cancer or Lou Gehrig's Disease (amyotrophic lateral sclerosis).

Exposure: A number of epidemiological studies and exposure surveys have given a significantly better description of the range of exposures to some aspects of the EMF mixture, both in the occupational and in the general environment (Portier & Wolfe, 1998), (Li et al., 2002), (Lee et al., 2002), (Zaffanella & Kalton, 1998), (Zaffanella & Hooper, 2000). It has become clear that the 24-hour average of the minute-by-minute 50-60 Hz magnetic field exposures is primarily influenced by stray ground currents, internal wiring, and the power grid rather than by appliances. Maximum fields (the highest exposure during the day) are probably contributed by use of appliances, electrical transportation, or passing briefly by internal wires, current-bearing plumbing, or very close to above or below ground power lines.

Which Aspects of the "EMF Mixture" Might Be Bioactive?: As the decade of the 1990s began, a few childhood leukemia studies suggested that associations were stronger between leukemia and proximity to power lines than between the disease and measured fields (NAS et al., 1997). With more studies, this pattern has disappeared (Greenland et al., 2000). The earlier impression led to investigations of correlates with power lines and measured magnetic fields. Resonance between the static magnetic field of the earth and alternating 60 Hz fields was evaluated, as were transient changes in magnetic field, as potential explanations for the epidemiology. As indicated on page 32, the results do not strongly implicate these aspects of the EMF mixture (Kaune et al., 2002).

A new hypothesis has arisen (Kavet et al., 2000), (Dawson et al., 2001). It proposes that contact currents from low frequency voltages, and not exposure to magnetic fields, might explain some of the epidemiological associations. Others (Graham and Ludquist personal communication, 2001) suggest that the high frequency components of these currents are bioactive. In occupational settings, micro-shocks have been invoked to explain the persistent association between magnetic field exposure and ALS (NRPB, 2001b), (Ahlbom, 2001). These hypotheses have not yet been tested.

Scattered associations with electric fields have been reported (Coghill, Steward & Phillips, 1996), (Miller et al., 1996), but this association has not been consistent. A hypothesis and some evidence have developed with regard to electric fields near transmission lines and their effects on the charge and concentration of particulate air pollutants (Henshaw et al., 1996). If true, this would suggest that one should bury lines to block their electric fields and that rephasing would not be effective. However, this hypothesis has not been sufficiently supported by evidence.

Two recent studies of miscarriage and personal EMF exposure suggest that maximum fields or average change between consecutive exposures may convey risk (Li et al., 2002), (Lee et al., 2002). Studies of the effect of personal exposure on urinary melatonin metabolites in utility workers have suggested the possibility that the rate of change of the magnetic field may be bioactive (Burch et al., 1998). This, too, would have implications for any mitigation. One laboratory has reported that the super-imposition of random EMF noise in the laboratory can block the effects of orderly low-frequency magnetic fields (Litovitz et al., 1994). No replication of this study has been attempted yet.

Radio Frequency Research: Public concern and research on the question of radio frequency and low-frequency-modulated radio frequency have increased in the last decade. Although this area may turn out to be relevant to the low frequency literature reviewed here, exploration of it was beyond the resources, mandate, and expertise of the review team.

Funding: Funding for EMF research in the United States has dropped from the levels in the late 1980s. The Department of Energy research program of $10 million per year has been eliminated and the amount of resources devoted to EMF research by the utility industry and the Electric Power Research Institute has decreased from $10 million per year at its peak to $3.5 million in 2000. The National Institutes of Health have no special study section with EMF experts to review research proposals in this area, so proposals are judged by experts in other areas and compete for scarce research dollars.

3 How to Read This Document

This document is not just a summary of the facts from the vast literature on the possible health effects of extremely low frequency (ELF) electric and magnetic fields. Instead the bulk of the main document presents a much more detailed rationale for the conclusions drawn, and the evidence is summarized in graphical and tabular form.

In preparation for this evaluation, the California EMF Program held a two-day epidemiology workshop to discuss some of the most relevant epidemiological findings and methodological issues. The proceedings of that workshop, which were pivotal to some of the conclusions reported here, were published in a peer-reviewed Supplement (5) of the journal *Bioelectromagnetics* on January 22, 2001.

4 What is New in this Evaluation

New Evidence

There have been many adequate reviews, including some very recent ones (NAS et al., 1997), (Portier & Wolfe, 1998), (IARC, 2001). The NIEHS review, in particular, was regarded as the starting point for this evaluation. The NIEHS Working Group carried out their evaluation in June 1998. Several important studies have been published between the conclusion of the NIEHS Working Group review and this evaluation, including three major studies on childhood leukemia (Green, Miller & Agnew, 1999b), (Green et al., 1999a), (McBride et al., 1999), (UKCSS, 1999). The deadline for including studies in our evaluation was June 24, 2000. This is later than the deadline originally mentioned in the Risk Evaluation Guidelines (REGs). Since the DHS evaluation began later than initially envisaged, the reviewers felt that it was unwise to disregard recently published, and possibly important, studies simply to observe a previously set but otherwise arbitrary date. Only one large study (van Wijngaarden et al., 2000) that dealt with suicide emerged during this extended deadline period.

In addition, the reviewers considered studies sponsored by the California EMF Program (Li et al., 2002), (Lee et al., 2002) and in the Epidemiology Workshop satisfying the criteria for inclusion in this evaluation, as specified in the Guidelines. In this final draft, the DHS scientists also discuss articles that were brought to their attention during the public comment period.

The document has features that were not present in the NIEHS document. One of these—presenting a graded degree of certainty of causality—was described above. Also discussed are the aspects that make up the EMF mixture that characterizes the exposure of persons who come near the power grid, the internal wiring of houses, and common household appliances. These are described in Chapter 3. The reviewers stress the notion of "mixture" because different aspects of EMF exposure (e.g., 60-cycle magnetic fields and high-frequency transients) would require different actions for abatement. For each of the diseases considered, there are explicit discussions about whether the epidemiological associations observed, if real, would convey a risk from lifetime exposure that would be of regulatory interest. This is a parameter of interest to the social justice policy framework, which focuses on the individual risks of the most highly exposed. In Table IX, the baseline mortality for conditions considered possibly associated with EMFs are discussed. The reviewers ask if the attributable burden of mortality from even a very small fraction of that baseline would be of regulatory interest when compared to the mortality burden thought to be avoided by regulation of other agents. The attributable burdens of mortality or morbidity are parameters of interest to the utilitarian policy framework, which aims at the most good for the most people at the least cost. The document also attends to any evidence suggesting inequitable exposure or vulnerability to EMFs. This is relevant to the environmental justice policy framework, which is concerned with unfair distributions of risk.

Each health condition considered had at least two epidemiological studies in which there was a statistical association with some surrogate for EMF exposure. The list of conditions is similar to that discussed in the NIEHS document and includes

- Adult and childhood leukemia
- Adult and childhood brain cancer
- Male and female breast cancer
- *EMF as a "broad spectrum" carcinogen for all cancers*
- Miscarriage
- Other reproductive and developmental conditions
- Amyotrophic lateral sclerosis (Lou Gehrig's Disease)
- Alzheimer's disease
- Acute myocardial infarction

- Suicide
- Other adverse non-cancer health outcomes (depression, electrical sensitivity)

5 Qualitative Bayes or Degree of Certainty Approach to Evaluation

The DHS scientists found the usual process of describing the pattern of evidence in some detail and then expressing an opinion (without explaining the rationale for that opinion) to be insufficiently transparent. Accordingly, they supplement the usual IARC procedure with an additional form of presentation and an additional form of judging whether EMFs are a cause of disease. The following table shows the questions that were systematically addressed. For definitions of epidemiological terms in the table see pages 20-22 (Sections 12.1.1-12.1.3).

TABLE II. QUESTIONS RELEVANT TO DEVELOPING A DEGREE OF CERTAINTY ABOUT CAUSALITY

EXPLANATIONS OF A STATISTICAL ASSOCIATION OTHER THAN A CAUSAL ONE
Chance: How likely is it that the combined association from all the studies of EMF and disease is due to chance alone?
*Bias: How convinced are the reviewers that EMFs rather than a study flaw that can be **specified and demonstrated** caused this evidentiary pattern? If no specified and demonstrated bias explains it, how convinced are they that EMFs caused these associations rather than **unspecified** flaws?*
*Confounding: How convinced are the reviewers that these disease associations are due to EMFs rather than to another **specified and demonstrated** risk factor associated with EMF exposure? If not due to a specified risk factor, how convinced are they that they are due to EMFs rather than to **unspecified** risk factors?*
Combined effect: How convinced are the reviewers that these disease associations are due to EMFs rather than to a combined effect of chance and specified or unspecified sources of bias and confounders?
ATTRIBUTES SIMILAR TO HILL'S (HILL, 1965) THAT ARE SOMETIMES USED BY EPIDEMIOLOGISTS TO EVALUATE THE CREDIBILITY OF A HYPOTHESIS WHEN NO DIRECT EVIDENCE OF CONFOUNDING OR BIAS EXISTS
Strength of association: How likely is it that the meta-analytic association is strong enough to be causal rather than due to unspecified minor study flaws or confounders?
Consistency: Do most of the studies suggest some added risk from EMFs? How likely is it that the proportion of studies with risk ratios above or below 1.0 arose from chance alone?
Homogeneity: If a large proportion of the studies have risk ratios that are either above or below 1.0, is their magnitude similar (homogeneous) or is the size of the observed effect quite variable (heterogeneous)?
Dose response: How clear is it that disease risk increases steadily with dose? What would be expected under causality? Under chance, bias, or confounding?
Coherence/Visibility: How coherent is the story told by the pattern of associations within studies? If a surrogate measure shows an association, does a better measurement strengthen that association? Is the association stronger in groups where it is predicted? What would be expected under causality? Under chance, bias, or confounding? How convinced are the reviewers that the magnitude of epidemiological results is consistent with temporal or geographic trends?
Experimental evidence: How convincing are the experimental pathology studies supporting the epidemiological evidence? What would be expected under causality, bias, chance, or confounding?
Plausibility: How convincing is the mechanistic research on plausible biological mechanisms leading from exposure to this disease? What would be expected under causality, chance, bias, or confounding? How influential are other experimental studies (both in vivo and in vitro) that speak to the ability of EMFs to produce effects at low dose?
Analogy: How good an analogy can the reviewers find with similar agents that have been shown to lead to similar diseases? What would be expected under causality, chance, bias, or confounding?
Temporality: How convinced are the reviewers that EMF exposure precedes onset of disease and that disease status did not lead to a change in exposure?
Specificity and other disease associations: How predominantly are EMFs associated with one disease or subtypes of several diseases? What would the reviewers expect under causality, chance, bias, or confounding? How much is their confidence in EMF causality for disease X influenced by their confidence that EMFs cause disease Y?

As a heuristic device, and following Hutchinson and Lane (Hutchinson & Lane, 1980), the REGs suggested that these questions about the pattern of evidence be posed so that one could say the pattern is more likely under the hypothesis that EMFs contributed to the cause of that health condition or more likely under the hypothesis that chance, bias, or confounding produced the pattern. This allows the reviewers to provide the reader a rationale for the relative weight given mechanistic, animal pathology, and epidemiological evidence and to understand which parts of the evidence suggest causality and which speak against causality.

The DHS reviewers coined the term "Qualitative Bayes Approach" to characterize a form of verbally justifying judgments about hazard that paid attention to the insights of Thomas Bayes, an 18th-century mathematician. His insights would suggest starting with some initial degree of certainty that any given agent is capable of being harmful based on knowledge about agents in general. Evidence is then accumulated on this specific agent and this changes the degree of suspicion or certainty. Imagine a prehistoric hunter deciding whether to try out some jungle fruit he has never seen before. He has an initial degree of suspicion high enough that he does not partake right away. He takes some fruit home and feeds it successively to several types of captured birds. As each species seems to survive, it seems less and less likely that the fruit would be harmful to humans. But since the leaves of the tree bearing that fruit resemble those from a tree that bears a poisonous fruit (causing the initial suspicion to be very high) the hunter's specific experiments might still leave him fairly suspicious and lead him to cruelly feed the fruit to a captive from another tribe. Only if the captive survived would his initial suspicions be allayed. This example illustrates Thomas Bayes's two key insights. As evidence builds we update our degree of certainty of harm, but, at any point in time, that updated degree of certainty also depends on how suspicious we were initially. This idea is expressed mathematically by a simple formula. The first term of the Bayes formula is the "prior odds," that is, the odds that a given hypothesis is thought to merit *a priori*, before examining the evidence. In this document it is called the prior because it is not based on subsequent research.

The second term, the "likelihood ratio," is a multiplier, calculated (or, in this case, qualitatively discussed) after scientific evidence has been collected and evaluated. The term "likelihood ratio" is most properly restricted to the case where one compares the statistical likelihood of a result under one specific hypothesis relative to that under another hypothesis, usually the null. It expresses the likelihood of the observed pattern of evidence if EMFs do indeed cause disease, divided by the likelihood of that pattern if EMFs do not cause disease. The third term, the "posterior," is the product of the first two and represents the odds of the risk being true after the prior has been modified by our evaluation of the evidence.

Because of the difficulty of translating complex evidence into numbers, we only use the ideas behind the formula as a way of explaining how certain or uncertain we were to begin with and to explain the basis for the weights we gave a particular stream of evidence in order to update our degree of certainty. The Bayesian perspective used by the California reviewers recognizes that a reassuring pattern of evidence from a stream of evidence that often misses a harmful effect does not allay one's suspicion much, even though an alarming pattern of evidence from that same stream of evidence might increase suspicion a lot. Going back to the hunter-gatherer example: if birds sometimes survive eating fruits that are lethal to humans, then reassuring evidence from bird experiments would not allay suspicion as much as the death of the birds after eating the fruit would increase our suspicion. In the terminology of probability, the relative likelihood conveyed by a positive or negative result depends on the false-positive rate and false-negative rate characteristic of that stream of evidence. The mathematical basis for this insight is discussed in the REGs (www.dhs.ca.gov/ehib/emf). It resulted in realizing that any stream of evidence, judged by the extent to which it usually produced false-positive and/or false-negative results, could be classified into four possible types: 1) capable of strengthening OR weakening one's certainty, 2) predominantly capable of strengthening certainty (like the bird feeding example given above), 3) predominantly capable of weakening certainty and, 4) uninformative, neither capable of strengthening nor weakening one's confidence. While this structured discussion helped organize the reviewers' judgments, it did not involve a mathematical combination of weights as would be the case in a quantitative Bayes evaluation. It should be noted that the Hill's attributes are like the bird-feeding example. If they are present they strengthen confidence, but if they are absent, confidence falls only a little.

The DHS reviewers considered the following streams of evidence: biophysical evidence about the physical induction mechanism, research into physiological and pathophysiological mechanisms, research into animal pathology and epidemiological evidence. Clearly if all these streams of evidence were non-supportive, one's degree of certainty would fall, and if they were all supportive it would rise. If some streams of evidence are unsupportive and some are supportive, the DHS reviewers considered the inherent proclivity of each stream of evidence to give false positive or false negative results as a guide to what weight its results should be accorded. If apparently supportive evidence is shown clearly to be due to artifacts, this would lower the degree of certainty.

In the "Qualitative Bayes Approach" the DHS reviewers elicited their own expert judgment about the *a priori* (initial) probability of hazard after a special training session on how to avoid common errors of probabilistic estimation. It was important

to be explicit about the prior probability because some physicists were arguing on the basis of physical theory applied to simplified biological models of the cell, that any biological effect from residential EMFs was impossible and thus had a vanishingly small initial credibility. This meant that they would require extraordinarily strong specific evidence to change their initial impression. Previous risk assessments have not explicitly considered this issue.

The discussion then turns to the patterns of specific EMF evidence in biophysical, mechanistic, animal pathology, and epidemiological streams of evidence. Obviously, if all four streams of evidence pointed toward or away from an EMF effect, the reviewers' job would be easy. But what if some streams of evidence are supportive and some are not supportive? What weight should be given each stream of evidence? It was in the effort to address this problem that discussions of the inherent proclivity to give false positive and negative results came into play. This discussion was guided by a series of pre-agreed-upon questions described in the table above. The discussion included pro, con, and summary arguments. An example of such arguments are presented in the next table.

TABLE III. EXAMPLE OF PRO, CON, AND SUMMARY ARGUMENT

CHANCE		
AGAINST CAUSALITY	FOR CAUSALITY	COMMENT AND SUMMARY
(A1) Not all the associations (relative risks) are above 1.00 or statistically significant.	(F1) The narrow confidence limits in the meta-analytic summaries and the low likelihood of this pattern of evidence by chance leans away from chance as an explanation.	(C1) A non-chance explanation must be sought.

Considering this kind of structured discussion helped organize the reviewers' judgments, after he/she weighed all the information in the usual way, although it did not involve a mathematical combination of weights as would be the case in a quantitative Bayes evaluation. After consideration of this carefully structured discussion of the evidence (considering how much more—or less—likely the pattern of evidence would be if the risk hypothesis were true compared to the likelihood of that evidence if EMFs were safe), the reviewers expressed an expert judgment on the posterior probability of a causal relationship.

6 QUALITATIVE BAYES RISK EVALUATION COMPARED TO TRADITIONAL AND QUANTITATIVE BAYES RISK EVALUATIONS

The traditional risk assessment has a section in which a judgment is given as to whether the agent being evaluated is capable of causing cancer or some other adverse health effect. This is called the "hazard identification." The typical presentation is heavy in describing the relevant evidence and rather light in explaining the rationale for the conclusion. Often the weight, given mechanistic, animal pathology, and epidemiological streams of evidence, depends on a review panel's interpretation of adjectives which best describe the pattern of evidence. For example, is the pattern of evidence "sufficient" or should it be called "limited"? Can confounding and bias be "reasonably" discounted? Then there are pre-agreed-upon rules for combining the streams of evidence. Limited animal evidence plus limited epidemiological evidence results in one rank, sufficient animal evidence plus limited epidemiological evidence leads to another rank, and so forth. The combinatorial rules are straightforward, but the rationale for deciding that a stream of evidence is "limited" is not clearly defined and is subjective.

A completely quantitative Bayesian approach of the sort proposed by McColl et al. (McColl et al., 1996) or by Lindley (Lindley, 2000), would require assigning many quantitative parameters to a complex Bayesian Net model which would mathematically combine the subjectively assigned parameters to produce a posterior degree of certainty of causality. To the reviewers' knowledge, this kind of model has never been applied to any environmental agent. How experts such as physicians, combine streams of evidence to make judgements about causality has

been of great practical interest. As pointed out by Shortliffe (Shortliffe et al., 2001) there have been two general approaches. One is to infer statistically (Holman, Arnold-Reed & Klerk, 2001) or find by interview what rules experts usually employ. This assumes that the rules of thumb that experts use are optimal. As Holman (Holman et al., 2001) points out, however, this may not always be the case. The other approach is to use information to indicate what weights ought to be used. An example of this was de Dombal's (de Dombal et al., 1972) work using a Bayesian approach to diagnosing the acute abdomen on the basis of the prior probability of patients with certain diagnoses showing up in emergency rooms, and the relative likelihood of elements of medical history, physical signs, and laboratory test results in the several possible diagnoses. According to Shortliffe (Shortliffe et al., 2001), neither approach has so far been reduced to computer applications that render the combining of streams of evidence a cut and dried uncontroversial activity. It should be expected then, that the analogous task of risk evaluation will still rely on professional judgement and will not be free of controversy. For this reason, our stakeholders urged us to opt for transparency rather than computational elegance in our risk evaluation guidelines. In response to the third draft, the Electric Power Research Institute contracted with Professor Sander Greenland in late 2001 to prepare a quantitative Bayesian model based on the epidemiological evidence for childhood leukemia. Since his will be the only extant quantitative Bayesian epidemiological analysis, the reviewers contrast its proposed approach to their own. His model will provide a posterior dose-response curve based on a prior dose-response curve, the pooled epidemiological data, and prior estimates of selection bias and non-differential measurement bias. The all-important biophysical, mechanistic, and animal pathology streams of evidence will not be part of Greenland's model, although they could influence the prior dose-response curve in a subjective way. Calculations from Greenland's model would allow one to provide a probability that the posterior slope of the dose-response curve is not flat, that is, that there is some causal effect.

The following table compares the Qualitative Bayes evaluation to the traditional and to Greenland's Quantitative Bayes approach to risk evaluation as to a number of characteristics.

TABLE IV. COMPARISON OF USUAL RISK ASSESSMENT METHOD TO QUALITATIVE AND QUANTITATIVE BAYES METHODS

CHARACTERISTIC	USUAL METHOD	QUAL. BAYES	QUANT. BAYES
Evaluates all streams of evidence?	Sometimes	Yes	Focuses on epidemiology, other streams influence prior
Elicits prior probability?	No	Yes	Prior dose-response curve
Compares likelihood of each element of the evidence under the hazard and non-hazard hypotheses?	No	Qualitatively	Quantitatively with many of the parameters subjectively elicited
Pro, con, and summary arguments to make rationale transparent?	No, most risk assessments are skimpy in justifying hazard categories assigned	Yes	Not unless a supplementary document were to accompany the model
Combines relative likelihoods mathematically to derive posterior?	No	No	Yes, but in some versions non-epidemiol. evidence is folded into the prior subjectively
Elicits an expert posterior probability after considering all	No	Yes	No

CHARACTERISTIC	USUAL METHOD	QUAL. BAYES	QUANT. BAYES
elements of the evidence?			
Displays judgments of various judges separately?	Usually strives for semblance of consensus	Yes	Technically possible for different experts to elicit their own parameters
Frames intermediate degrees of certainty as "not a proven hazard?"	Often	No, reveals posterior probability	No, reveals posterior probability

Both the Qualitative Bayes and the Quantitative Bayes evaluations can provide a posterior degree of certainty that the epidemiological associations are causal, which, if in the range from 10 to 90 out of 100, will not seem trivial to the general public and will stimulate policy discussions. The statements, "possible," "there is no proven hazard," or "there is no consistent evidence," often used for this range of degrees of confidence, will not stimulate such discussions. Thus, both the Qualitative Bayes and Quantitative Bayes methods pose risk communication "problems" for those who believe that society should not begin policy discussions until most scientists are virtually certain that a hazard exists. The traditional hazard identifications would pose the same "problem" if they routinely used more nuanced categories of hazard assessment that distinguished between, say, a certainty level of 11/100 and one of 89/100. As now framed they pose a risk communication "problem" for those who believe that policy discussions should begin even before a hazard is firmly established.

Compared to traditional qualitative evaluations, the Qualitative Bayesian approach makes the evaluation more transparent, but it still accommodates different opinions. The DHS reviewers have no doubt that critics of their conclusions could use the Qualitative Bayes format to make their points. Some of the physicists who believe that they have a theory to prove that no residential EMF effect is possible would use priors so low that their posterior degrees of certainty would be low as well; the toxicologists who believe reassuring animal tests prove that EMFs are safe would make a case that the animal study results pull down their degree of certainty of a hazard to a level below their initial degree of certainty. In a contentious area such as EMFs, the reviewers doubt very much that any of the three styles of risk evaluation discussed in the table would force a consensus among subject matter experts who weigh and interpret the several streams of evidence differently. Even in the Quantitative Bayes model experts will use different priors and will elicit different subjective relative likelihood parameters for items like bias and confounding, for which there is no direct evidence. In the traditional method, experts will disagree on whether a stream of evidence warrants the adjective "limited" or "sufficient," and in the Qualitative Bayes approach experts will disagree on "how much more likely" the pattern of evidence is under the causal and non-causal hypotheses. But the reasons for these different judgments will be more transparent in the Qualitative Bayes style of risk evaluation and we believe that this is desirable in controversial areas.

7 How Credible Was the EMF Hypothesis to Begin With?

The three reviewers first considered the initial credibility of the hypothesis (before any targeted research had been done) that everyday residential and electrical occupational EMF exposures could influence the risk of disease. Like the majority of reviewers at IARC and NIEHS, the DHS reviewers were swayed only a little by theoretical biophysical arguments that such influences were impossible, since these arguments depend on assumptions about biological systems that may or may not be sophisticated enough to reflect reality and rule out an effect. The reviewers acknowledged, though, that this was probably the only agent they had encountered where these kinds of "impossibility" arguments had been made. However, a better understanding of biology (and not any change in physics theory) could conceivably explain how an organism could detect and be affected by the spatially and temporally coherent EMFs or other aspects of the EMF mixture emanating from power lines and appliances.

The reviewers considered the proportion of chemical agents that had tested positively for carcinogenicity at high doses (about 20%) as one benchmark (Fung et al., 1993). They also considered the fluctuation of disease rates starting in the late 19th century when electricity began to spread gradually from wealthy urban areas to other parts of the world. Any changes could put *a priori* bounds on the size and direction of any EMF effect. Milham (Milham & Ossiander, 2001) drew attention to

something that Court Brown and Doll (Brown & Doll, 1961) had pointed out more than 40 years ago, that an increased risk of leukemia mortality for 2- to 4-year-old children first appeared in the 1920s and increased in intensity in the 1940s. Thus some factor(s) (perhaps electricity, perhaps accuracy in diagnosis), in those modernized locations caused the registration of toddler leukemia deaths to increase threefold. The evidence from Court Brown, Doll, and others that childhood leukemia mortality registration had indeed increased during the early 20th century increased the prior probability of a moderately large EMF effect, at least for childhood leukemia. Since similar trends were not reported for other conditions, it was considered that modest protective or harmful effects from rare high exposures were compatible with the data.

The three DHS reviewers underwent special training in probability elicitation. They then judged that EMF effects were about as probable or a little less probable to influence the risk of disease as any man-made environmental pollutant taken at random. The three reviewers gave probabilities ranging from 5% to 12% *a priori*, that EMFs at or above the 95th percentile of typical residential US exposures would produce effects detectable by epidemiologists when compared to the 1st percentile of residential exposure or below.

8 The Weight Accorded Biophysical Arguments that Bioeffects from Residential and Most Occupational Fields were Impossible or that No Physical Induction Mechanism had Been Elucidated

While the reviewers do not doubt established physical theory, they believe that its application to simplified biological models is not sufficiently convincing to prove the impossibility of epidemiological or laboratory observations. However, the argument that environmental fields have very little energy lowered the prior probability that EMFs might have biological or pathological effects. The fact that there was no mechanistic explanation for how residential-level electric or magnetic fields might cause chemical or cellular changes, that there was no recognized molecule or organ capable of reacting or detecting residential magnetic fields, and the fact that recognized physiological effects of pulsed and very high magnetic fields did not have a well-understood physical induction mechanism did not decrease the updated degree of confidence much. This is because many known physiological and pathological effects go for a long time without a full mechanistic understanding.

9 The Weight Accorded Experimental Evidence On Any Pathophysiological Mechanisms by Which EMF Might Work

It has long been known that EMFs can affect biological processes, if their intensity is strong enough. In fact, safe exposure limits have been set to prevent these effects. A good review can be found in the book *Electromagnetic Fields (300 Hz to 300 GHz), Environmental Health Criteria 137*, published under the joint sponsorship of the United Nations Environment Program, the International Radiation Protection Association, and the World Health Organization (Geneva, 1993). In almost all cases, these levels are exceeded only in very rare occupational environments. Since they are almost never exceeded in the general environment, such levels are not a public health concern. A much more complex debate centers on whether these are the only possible effects or whether the temporal and spatial coherence of the man-made fields associated with electric power can be somehow discriminated from the incoherent endogenous currents and interact with biological processes at levels much lower than those for which exposure limits exist. The reviewers agreed that, as was also the case initially for many disease-causing agents, there is not a well-documented mechanism that explains how the EMF "mixture" at residential or occupational levels could initiate a biological response or, having initiated that response, how a chain of events could lead to damage or disease of various types. There are biological effects from aspects of the EMF mixture, particularly at exposure doses far above residential and occupational levels. At this time they do not provide a clear mechanistic understanding of how the EMF mixture could cause disease. The absence of a clear mechanistic chain of effects and the failure of many experiments with aspects of the EMF mixture to produce any mechanistic effects did not lower the reviewers certainty of causality much below what it was initially. The evidence that there are some mechanistic effects of some aspects of the EMF mixture at doses (thousands of mG) far higher than usually encountered in the environment did not boost the confidence of causality very much beyond the initial probability because the biophysical arguments suggest that they might not be relevant to effects at lower levels. The DHS reviewers accepted the unusually strict requirement that mechanistic results in the laboratory must be demonstrable at ambient levels of exposure.

It should be noted that the assumption of many of the mechanistic experiments is that the effects of magnetic or electric fields (like those of many chemicals and ionizing radiation) occur at a level of organization demonstrable in a chemical mixture, a mixture of cellular components, or a mixture of cells and does not depend on the presence of an intact multicellular organism. There are some well-recognized effects that violate these assumptions. For example, the intact shark, through a

special organ with an array of connected detectors, can detect tiny electrical fields emitted by distant prey. The exact biophysical mechanisms by which the individual detectors work cannot be documented using individual receptors at the ambient levels detected by the intact shark (Kalmijn, 1971), (Wissing, Braun & Schafer, 1988).

The lack of mechanistic understanding, which was initially the case for many harmful agents, is not as strong an argument against causality as the presence of such an understanding would be in favor of causality. Therefore the mechanistic line of evidence did not contribute much to the reviewers' judgments.

10 The Weight Accorded to Experimental Evidence not Clearly Connected With Particular Endpoints but Relevant to the Ability of Low-Level EMFs to Be Bioactive

A number of studies, both in vivo and in vitro, report bioeffects which, while they do not shed light on physical induction or pathophysiological mechanisms, do suggest that there are effects other than those mediated by well-understood mechanisms, such as induced currents. For example, the initial observations by Liburdy of inhibition of the melatonin antiproliferative action by 12 mG 60 Hz fields in 1993 (Liburdy et al., 1993) has been confirmed and extended by two other laboratories (Blackman et al., 2001), (Ishido et al., 2001). The series of studies using pulsed magnetic fields that showed non-robust effects on chicken embryos at intensities below 100 mG (Martin, 1988), (Berman et al., 1990), (Martin, 1992), (Moses & Martin, 1992), (Moses & Martin, 1993), (Martin & Moses, 1995), (Litovitz et al., 1994), (Farrell et al., 1997a), (Farrell et al., 1997b), (Leal et al., 1989), (Chacon et al., 1990), (Ubeda et al., 1994), (Koch & Koch, 1991), (Koch et al., 1993), (Singh & et al., 1991), (Espinar et al., 1997), (Blackman et al., 1988), (Yip et al., 1994a), (Yip et al., 1994b), (Coulton & Barker, 1991), (Youbicier-Simo et al., 1997), (Piera et al., 1992), (Pafkova & Jerabek, 1994), (Pafkova et al., 1996), (Pafkova et al., 1994), (Veicsteinas et al., 1996) also provide some evidence of bioeffects that would be considered "impossible" according to biophysical theory. These two areas of research have been greeted with suspicion. For example, Weaver (Weaver, Vaughan & Martin, 1999) dismisses in vitro effects as being artifactual, due to an insufficiently rigorous lack of temperature control, because biophysical theory suggests that tiny fluctuations in temperature would produce more effects than magnetic fields below 100 mG. The DHS reviewers were not convinced by this argument. These studies were no less rigorously conducted than most in vitro studies in other fields of research. There is no direct evidence that inducing magnetic fields also heats the tissues. If experimental controls beyond the current technological limits are required, then ALL in vitro and in vivo research should be called into question.

The reviewers had differing opinions on the extent to which this evidence should change the belief in the hypothesis from what it was when this issue was first raised. One could argue that any experiment that shows an effect where none is expected ought to increase the credibility that EMF can indeed interact with biological systems at energy levels that biophysical theory considers too low to be effective. These studies thus provide some grounds for mistrusting the prediction of simplified biophysical models that no effect is possible below 100 microTesla (μT). Reviewer 1 was compelled by the evidence as it stands, while the other two reviewers would require further experimentation to gain general acceptance of the results before putting a lot of weight on them. All three reviewers agreed that confirming or explaining away the results from these two groups of experiments would be important for those who put great weight on biophysical "impossibility" arguments.

11 The Weight Accorded to Animal Pathology Experiments

The reviewers agreed that, with few exceptions, animal pathology studies based on high exposures to certain aspects of the EMF mixture showed no effects. There were three reasons why the reviewers believed that animal bioassays of single ingredients of the EMF mixture might be prone to missing a true effect:

a) Finding the right animal species to test: While the reviewers recognized that most agents found to cause cancer in humans also cause cancer in some (but not all) animal species, they were also cognizant that there are known human carcinogens, such as cigarette smoke, alcoholic beverages, benzene, and arsenic, for which no animal model existed for many decades.

b) Testing one ingredient of a mixture: The reviewers all questioned whether the bioassay of one element of a mixture could be sensitive enough to detect problems in the entire mixture. For example, many reassuring assays on the carcinogenicity of caffeine would not reassure us about the carcinogenicity of coffee. The animal pathology studies to date have been on pure steady 60 Hz fields not on the mixture of ingredients found near power lines or appliances.

c) Assuming that high intensities of magnetic fields produce larger effects than moderate fields do: The reviewers also questioned the sensitivity of a bioassay involving a small number of animals and assuming a monotonically increasing risk from low to high-dose, when the epidemiological studies that prompted the bioassays did not suggest an ever-increasing response.

The epidemiology suggests that the effect, if any, at 100s of mG (Tynes, Reitan & Andersen, 1994b), (Floderus, Tornqvist & Stenlund, 1994), (Alfredsson, Hammar & Karlehagen, 1996), (Minder & Pfluger, 2001) is no greater than that of children at 3 mG (Greenland et al., 2000), or of highly exposed utility workers with 24 hr time weighted averages (TWAs) around 7 mG (Kheifets, London & Peters, 1997b), (Kheifets, 2001). One would not expect rodents at 1000 mG to demonstrate a large enough effect to be detected in a conventionally sized laboratory experiment with a few hundred animals.

Accordingly, the lack of response in most animal pathology studies did not lower the degree of certainty by much. Reviewer 1 and 3 had their degree of confidence increased somewhat by repeated, but unreplicated, results from one German laboratory (Mevissen et al., 1996b) and isolated results from two laboratories in the former Soviet Republics (Anisimov et al., 1996), (Beniashvili et al., 1991), which showed co-promotional effects on breast tumors. None of the reviewers were much influenced by the statistically significant increase in thyroid cancers in one of the bioassays (Boorman, McCormick & Findlay, 1999b), even though it had not appeared in control series of previous bioassays and was thus a very unlikely occurrence. This effect showed up in only one sex of rats and not in mice and thus did not pass conventional toxicological criteria for animal carcinogenicity.

12 The Weight Accorded to Epidemiology Combined with Other Streams of Evidence

In the reviewers' judgement, it was epidemiological evidence that produced the most change in the degree of certainty from what it was *a priori*. Epidemiological studies are non-experimental statistical studies of human populations that compare rates of disease in groups with different levels of exposure or compare the proportion of exposed subjects in groups of healthy and diseased persons. The weakness of epidemiological evidence is that one cannot rule out the effect of factors associated with EMFs ("confounders") or completely avoid the limitations of collecting evidence in the real world instead of a controlled laboratory environment. These limitations may introduce errors ("bias") in the results. On the other hand, the strength of epidemiology is that it deals with the species of interest (humans) and the mixture and dose of interest (the EMF mixture as experienced by humans).

The individual studies, most of which were described in the NIEHS report, have been summarized in tables and graphs in this report. A structured evaluation of the epidemiological evidence was carried out for each of the 13 endpoints and summarized with the classification used by IARC and also by a statement of the degree of certainty that the observed epidemiological associations were causal in nature. In evaluating the credibility of epidemiological evidence, it is common to consider whether the risk being studied is "biologically plausible" and if "experimental evidence" exists to support the epidemiology. The three reviewers followed this practice considering the impact on the epidemiological findings of mechanistic evidence and evidence about bioactivity at near ambient levels under the heading of "plausibility" and of the animal pathology under the heading of "experimental evidence." However, these non-epidemiological studies were discussed in detail in separate chapters.

12.1 Issues Relevant to the Evaluation of the Epidemiological Evidence

Epidemiological results, because of the limitations of the data collected in a "real world" environment, need to be evaluated with particular care. The three major concerns are the effects of chance, bias, and confounding.

12.1.1 Chance

Epidemiological studies are expensive. Moreover, in the case of EMF and cancer, it may be virtually impossible to find sufficient subjects with both a rare disease and the rare high exposures. The very well-conducted studies carried out in some Scandinavian countries are based on so few subjects that a single additional case of cancer would change their findings. It is possible to reduce the effect of chance findings by combining results from a number of studies in a meta-analysis or even to merge the data collected for different studies in one large data set (pooled analysis). For health endpoints such as childhood leukemia (Greenland et al., 2000), adult leukemia (Kheifets et al., 1997a), adult brain cancer (Kheifets, 2001), amyotrophic lateral sclerosis (Ahlbom, 2001), male breast cancer (Erren, 2001), and miscarriage (Lee et al., 2002), (Li et al., 2002), pooled or meta-analytic analyses achieve conventional "statistical significance." This could be interpreted as follows: If these were randomized experiments without the possibility of bias or confounding, the statistical associations found would not be expected to occur by chance in 5 or fewer experiments out of 100 replications, if there really was no effect. Of course, epidemiological studies are not experiments, and it would be unethical and impractical to experimentally subject large numbers of humans to potentially harmful agents. This leads to the consideration of bias and confounding.

12.1.2 Bias

Any source of error in collecting the data may introduce a bias, which is a reason why the apparent result might not be the truth. A very common bias results from errors in assessing the true exposure of the subjects to the agent of interest, in this

case EMFs. Provided exposure of cancer cases and healthy controls is not assessed differently, this bias on average results in an underestimate of the risk, if one exists. When comparing the health risk of subjects exposed above one value to that of subjects below that value, non-differential misclassification of exposure* would not, on average, show an association if one does not truly exist. However, it may inflate the risk of intermediate exposure subjects and thus frustrate attempts to estimate a dose-response function. In most of the EMF studies, measurements were not taken for a long enough duration during the induction period of the disease to avoid this kind of misclassification. And there is even some argument about whether the right aspect of the EMF mixture has been measured. The three reviewers concluded that all of this may have led to an underestimate of any true effect of high versus low exposures and may have frustrated the ability to develop an appropriate dose-response curve.

Of the many errors that can creep into epidemiological studies, one in particular has been a source of argument with regard to a subset of the EMF epidemiological studies. We are referring to "selection bias" in some of the case control studies. A case control study is analyzed by comparing a series of cases with a disease to a series of healthy subjects as to their EMF exposure. If the cases display a higher proportion of high EMF exposure than the controls, this suggests a causal effect of EMFs. If, however, the probability of being selected for study is influenced both by whether one has the disease AND whether one had a high EMF exposure, then an apparent difference will appear between the cases and the healthy controls, which is the result of this biased selection and the result does not reflect any true effect of EMFs on the disease. One way to recruit healthy subjects is random telephone contact. This method excludes subjects of lower socio-economic status (SES), who may not have a telephone. Experience has shown that healthy controls of lower SES are sometimes less likely to participate in epidemiological studies than upper class subjects. In some studies, lower class subjects are more likely to live in neighborhoods with nearby power lines (Bracken et al., 1998). Since cancer patients of all social classes are easier to recruit (through a cancer registry) and more likely to be interested in participating, the effects of non-representative control selection may distort the comparisons between cases and controls and, therefore, the study results. In the case of EMF, it is claimed that the fact that there are more subjects living close to power lines among the cancer patients than among the healthy controls could be due to the fact that low SES subjects are more likely to live close to power lines and they are underrepresented in the control group. This issue of possible selection bias in case control studies is a particular issue for the North American case control studies on childhood leukemia. Hatch (Hatch et al., 2000) indicate that the association between childhood acute lymphoblastic leukemia (ALL) and front door magnetic fields greater than 3 mG was 1.9 (1.1-3.27) among full participants in their study but fell to 1.6 (0.98-2.61) when 147 partial participants were included. Although this difference was well within sampling variability, she suggested that it might be evidence of the presence of a selection bias which might be even more extreme if non-participants had their front doors measured and had been included in the analysis. Hatch (Hatch et al., 2000) concluded that "while confounding alone is unlikely to be an important source of bias....selection bias may be more of a concern...in case-control studies." The Scandinavian studies relied on cancer registries and lists of citizens and did not require permission of the subjects so that selection bias was not a problem. Ahlbom (2001) has shown that the results of the two groups of studies are not much different. The pooled analysis of all the studies he dealt with showed a relative risk for exposures above 4 mG as 2.0 (1.3-3.1), while the results after excluding the US studies was 1.7 (1.0-2.8). That is, the confidence interval of the two risk estimates overlap, indicating that there may or may not be some overestimate of the effect of living near power lines in the American studies, but that even if these are excluded, the association remains statistically significant. In the pooled analysis by Greenland et al. (2001), there was an effect of power line proximity ("wire code"), as well as an effect of measured magnetic fields. This might indicate some selection bias for power line proximity. Nonetheless, magnetic fields come only partially from power lines. Internal wiring and currents on plumbing form an important source (Zaffanella & Kalton, 1998). The only evidence we know of that examines personal EMF exposure from all sources and its relation to social class (Lee GM & Li D-K, personal communication) does not suggest differences in personal EMF exposure in different social classes. The evidence linking EMFs and adult leukemia, adult brain cancer, Lou Gehrig's disease, and Li's prospective miscarriage study come largely from study designs where selection bias is not possible (studies where rosters of healthy workers or subjects of high and low exposure are followed until death or health outcomes are determined from available records without requiring subject cooperation). Thus, although selection bias may have distorted the associations between EMF and childhood leukemia in some of the studies, the three reviewers did not believe that it totally explained the childhood leukemia findings and selection bias was not even an issue in the bulk of the studies related to adult leukemia, adult brain cancer, ALS, or in one of the two recent studies on EMF and miscarriage.

* "non-differential misclassification of exposure" is said to occur when errors of measurement occur equally in cases of disease and in healthy controls.

12.1.3 Confounding

The term "confounding" is derived from the Latin "confundere," to melt together. Epidemiologists use the term when the impact of two risk factors "melt together" and must be disentangled. If heavy alcohol consumption and smoking are both known to cause esophageal cancer, and people who drink also tend to smoke, then the effect of drinking will confound the effect of smoking and vice versa. Therefore one must correct for this confounding in the way the data are analyzed. Sometimes the non-effect of a factor which conveys no risk at all is confounded with the true effect of another factor. For example, it has been suggested that people who live near power lines also live on busy streets with lots of traffic and air pollution. This argument suggests that the effect of air pollution on childhood leukemia was confounded with the non-effect of the power lines, and the power lines were falsely implicated instead of the air pollution. Two conditions must pertain for an agent to be a strong confounder of the EMF effect on the various diseases discussed in this report. That agent must be strongly correlated with EMF exposure and it must have an effect on the studied disease that is even stronger than the apparent effect of EMF. If it is weakly correlated with EMF exposure it must have an effect on disease that is very strong indeed if it is to make EMF falsely appear to have an effect. Langholz (Langholz, 2001) has examined the candidate confounders for childhood leukemia and their association with power line proximity wire code. He concluded that while something connected with the age of home was a possibility, factors like traffic density, ethnicity, and smoking were not likely confounders. Indeed, not all studies of traffic and childhood leukemia suggest it as a risk factor (Reynolds et al., 2001), but a recent study of traffic and power line proximity and childhood leukemia (Pearson, Wachtel & Ebi, 2000) did suggest that there might be a joint effect. Hatch (Hatch et al., 2000) examined a variety of socioeconomic, and other confounders, and concluded that together, or alone, measured confounders would distort the association with ALL by less than 15%. Hatch also found no association between residential mobility, magnetic fields, or leukemia unlike Jones (Jones et al., 1993).

Electric shocks have been invoked to explain the relation between high-exposure jobs in the utility industry and ALS (Ahlbom, 2001), (NRPB, 2001a). If this were confirmed, they might also be invoked to explain the adult leukemia and brain cancer associations on the as yet unproven assumption that shocks could somehow cause cancer. However, the literature linking shock to ALS, unlike much of the literature linking high-EMF exposure jobs to ALS, depends on subjects remembering shocks. They are thus more vulnerable to recall bias than the EMF studies. Some of the studies suggest a protective, not a harmful, effect (Cruz et al., 1999); (Kondo & Tsubaki, 1981), (Gunnarson et al., 1992) and the size of the harmful effects of shock are less than the high EMF job effect (Deapen & Henderson, 1986), (Savettieri et al., 1991). No published study has demonstrated a correlation between shocks and high-EMF exposure jobs. Studies are underway to see if grounding currents are associated with measured magnetic fields and power line proximity. The three reviewers felt that the evidence for the confounders that had been proposed for EMF exposure did not have strong support and therefore their degree of confidence was not decreased by the pattern of evidence.

12.1.4 Combined Effect of Chance, Bias, and Confounding

Although each of these possibilities by itself is unlikely to explain the association between EMF and cancer, is it possible that a combination of the three may be responsible for an artifactual finding? The DHS reviewers considered this possibility and concluded that this is not a credible explanation when many studies of different design have reported similar results. It is not impossible that individual studies may have their result completely explained by an extraordinary coincidence in which independent unlikely events occur simultaneously. However, for many diseases considered here the general pattern of results is not critically dependent on accepting each individual study as reliable. For example, in the case of childhood leukemia, it has been repeatedly shown that, even if a few studies are excluded, the results of meta-analyses, pooled analyses, or sign tests are not significantly altered.

In conclusion, the DHS reviewers, to different degrees, concluded that chance, bias, and confounding are not probable explanations for the reported associations when they have been reported repeatedly by independent investigators. In addition, the DHS reviewers considered other criteria, notably the Hill's criteria for causality, keeping in mind that these are not to be considered as strict rules to follow. Apart from consistency, which, as noted above made them doubt the non-causal explanation for a few endpoints, none of the Hill's attributes, when applied to the pattern of evidence, influenced their degree of certainty by much.

The DHS reviewers recognize the size of the associations between EMF exposure and the various diseases studied are not so far above the resolution power of the studies that confounding and bias could be definitively ruled out as explanations. They recognized that there was rarely an orderly progression of increased risk within studies and that the effects reported for groups with dramatically high exposures like electric train operators did not display dramatically high risks when compared to those with low or moderate exposures. There are also examples where the statistical results are not completely coherent. However, these evidentiary tests are prone to giving false negative results due to non-differential measurement error and sample size problems. Also, EMFs may have societally important effects that

are nonetheless truly close to the detection of epidemiology. Finally, an agent may act in an "on/off" fashion and would not produce a steadily increased effect. These patterns of evidence therefore lowered confidence some, but not a lot.

13 Conclusions

Having examined and discussed each of the health endpoints mentioned above in a separate chapter in the main document, the three DHS reviewers each assigned their best judgment IARC classification and degree of certainty (as a number between 0 and 100). These determinations are summarized in Table V. Column 1 displays the condition considered. Column 2 identifies the reviewer. Column 3 shows the IARC classification in which the number "1" denotes a definite hazard: "2A" a probable hazard, "2B" a possible hazard, and "3" evidence "inadequate" to make a classification. Column 4 displays the pre-agreed-upon phrases for describing zones of certainty. Column 5 shows the ratio of the reviewers imputed posterior odds to the reviewers imputed prior odds (more about this below). In column 6, the reviewers graphed their best-judgment degree of certainty as an "x" and indicated their uncertainty with a shaded bar on either side of that best judgment.

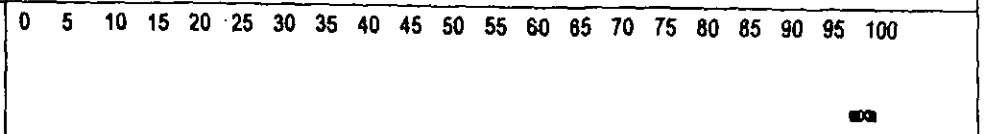
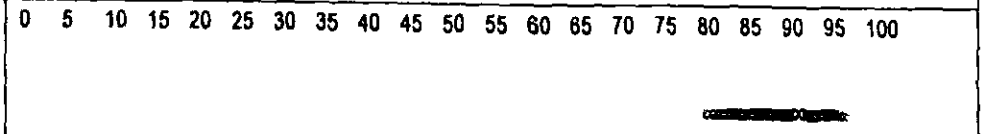
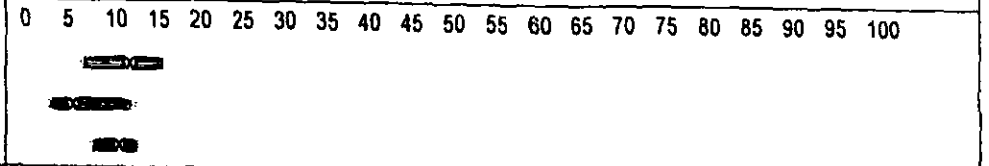
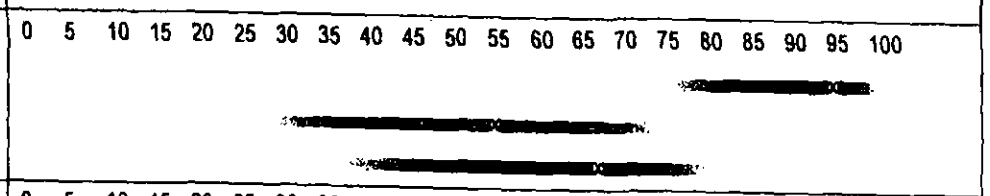
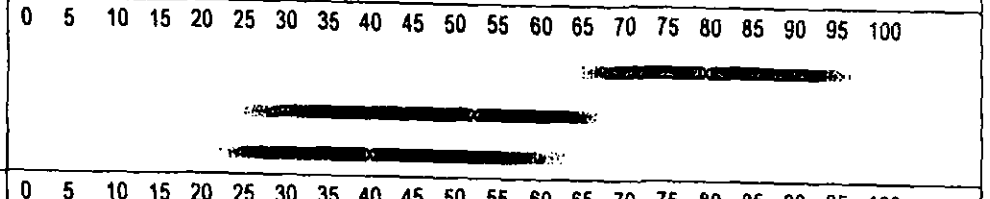
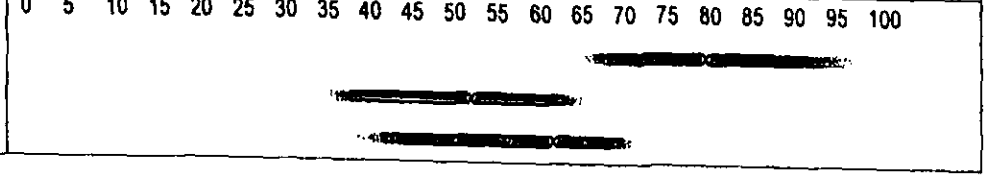
To provide an illustration, this method has been applied to two non-EMF examples in the first two rows. In row 1, Reviewer 2 has indicated that air pollution is a definite causal trigger of asthma attacks and that he is virtually certain of this. In row 2 he shows that he strongly believes that particulate air pollution causes excess deaths. There is relatively little uncertainty around either of these determinations.

Row 3 displays the prior degree of certainty that there would be epidemiologically detectable effects when comparing disease rates among persons exposed to EMFs at or above the 95th percentile of US residential levels to rates at or below the 1st percentile residential exposure. These prior degrees of certainty range from 5 to 12 on a scale from 0 to 100.

Column 5 is labeled "IRL" for "imputed relative likelihood." If the degree of certainty is converted to a probability scale (0–1.0) and, in turn, if one converted the probability to odds (probability/(1–probability)) the imputed prior odds can be compared to analogously calculated imputed posterior odds. One would base these on the "best judgment" posterior degrees of certainty graphed in Table V. The resulting "imputed relative likelihoods" provide some indication of how much the overall pattern of evidence in biophysics, mechanistic, animal pathology, and epidemiological streams of evidence have combined to move the reviewers from their respective starting degrees of certainty. For example, with regard to air pollution triggering asthma attacks, the existing evidence has caused Reviewer 2 to move 900-fold from his prior, while the childhood leukemia evidence has moved him 22-fold*. Royall (Royall, 1997) has suggested anchoring the interpretation of such relative likelihood numbers on the relative likelihoods derived by probability theory from the following hypothetical experiment: Suppose that a reviewer has two urns, one that contains only white balls, the other that contains half white balls and half black balls. He takes one of the two urns at random. To determine which urn he has ended up with, he begins repeatedly withdrawing a ball and then replacing it in the urn (after noting down its color) and mixing up the balls before pulling out yet another ball. If on only one draw he were to find a black ball, he would know that he was dealing with the urn containing 50% black balls. But what is the relative likelihood conveyed by drawing one or more consecutive white balls? Royall demonstrates that drawing 5 white balls in a row conveys a relative likelihood of 32, while drawing 10 consecutive balls conveys a relative likelihood of 1,024. Reviewer 2 views the asthma/air pollution data as being almost as strong as the evidence conveyed by drawing 10 consecutive white balls during the urn experiment, while the childhood leukemia evidence is equivalent to drawing just shy of 5 consecutive white balls.

* Reviewer 2 had a prior of 5 and a posterior for childhood leukemia of 54. The prior odds are 5/95 = 0.0526. The posterior odds are 54/46 = 1.174. The imputed relative likelihood is 1.174/0.0526 = 22.3.

TABLE V. PRIOR AND POSTERIOR DEGREES OF CERTAINTY AND DHS REVIEWERS' APPLICATION OF IARC CLASSIFICATION

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
Air Pollution Triggered Asthma Attacks (Example: Not EMF-Related)	2	Human Risk	Virtually Certain	931	
Particulate Air Pollution Triggered Deaths (Example: Not EMF-Related)	2	Prob. Risk	Strongly believe	171	
Prior Confidence that EMFs Could Cause Epidemiologically Detectable Disease	1	N.A.	Prone not to believe	1	
	2		Strongly believe not	1	
	3		Strongly believe not	1	
Childhood Leukemia	1	1	Strongly believe	140	
	2	2B	Close to dividing line	22	
	3	2A	Prone to believe	17	
Adult Leukemia	1	1	Prone to believe	29	
	2	2B	Close to dividing line	21	
	3	2B	Close to dividing line	6	
Adult Brain Cancer	1	2B	Prone to believe	29	
	2	2B	Close to dividing line	20	
	3	2B	Close to dividing line	13	

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
Childhood Brain Cancer					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	7	
	2	3	Prone not to believe	2	
	3	3	Prone not to believe	3	
Breast Cancer, Female					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	7	
	2	3	Prone not to believe	3	
	3	3	Prone not to believe	2	
Breast Cancer, Male					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	6	
	2	3	Prone not to believe	12	
	3	3	Prone not to believe	2	
EMF Universal Carcinogen?					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Strongly believe not	0.4	
	2	3	Strongly believe not	0.5	
	3	3	Strongly believe not	0.2	
Miscarriage					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	2B	Close to dividing line	9	
	2	2B	Close to dividing line	20	
	3	2B	Close to dividing line	11	
Other Reproductive					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Strongly believe not	0.4	
	2	3	Strongly believe not	0.8	
	3	3	Strongly believe not	0.2	

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
ALS (Lou Gehrig's Disease)					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	2B	Close to dividing line	9	
	2	2B	Close to dividing line	21	
	3	2B	Close to dividing line	11	
Alzheimer's					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	5	
	2	3	Prone not to believe	4	
	3	3	Prone not to believe	2	
Suicide					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	6	
	2	3	Close to dividing line	15	
	3	3	Close to dividing line	7	
Heart					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	6	
	2	3	Prone not to believe	8	
	3	3	Prone not to believe	3	

14 How different is this evaluation from the NIEHS, NRPB, and IARC findings?

As outlined in Table VI below, there are both common points and significant differences between the EMF Program's evaluation and those carried out at about the same time by the NIEHS (for the Federal EMF-RAPID Program), the NRPB (NRPB, 2001a), (NRPB, 2001b), and the IARC (*Note: The NRPB did not use the IARC classification system but expressed their conclusion using common language expressions*).

The following table compares these evaluations:

Table VI. A Comparison of DHS Reviewers' Degree of Certainty with That of Other Agencies

HEALTH OUTCOME	NIEHS WORKING GROUP	IARC	NRPB	DHS
Childhood Leukemia	2B*	2B	Possible	2B to 1
Adult Leukemia	2B* (lymphocytic)	Inadequate	Inadequate	2B to 1
Adult Brain Cancer	Inadequate	Inadequate	Inadequate	2B
Miscarriage	Inadequate	Not considered	Not considered	2B
ALS	Inadequate	Not considered	*Possible but perhaps due to shocks*	2B
Childhood Brain Cancer, Breast Cancers, Other Reproductive, Alzheimer's, Suicide, Sudden Cardiac Death, Sensitivity	Inadequate	Inadequate or not considered	No for Parkinson's Disease, Inadequate for Alzheimer's, Other endpoints not yet considered	Inadequate

It is clear from Table VI that, when applying the IARC guidelines, the DHS reviewers agreed with IARC and NIEHS reviewers that in many cases (e.g., childhood brain cancer and male and female breast cancer) *the evidence would be classified by* IARC as inadequate to reach a conclusion. One of the DHS reviewers agreed with the IARC and NIEHS on childhood leukemia. Two of the reviewers agree with NIEHS, *but not with IARC, on adult leukemia.* All three reviewers agreed with NRPB that EMF was a "possible" cause of ALS. Otherwise, the DHS reviewers regard the EMFs association more likely to be causal than NRPB, IARC, or NIEHS did.

It should be noted that all of the review panels thought that the childhood leukemia *epidemiology warranted* the classification of EMF as a "possible" carcinogen and thus did not agree with the biophysical arguments that EMF physiological effects (and therefore pathological effects) were *"impossible."*

There is a wide range of opinions in the scientific community as to the probability *that EMFs cause health problems.* The DHS reviewers provided numerical values for their degrees of confidence that risk of various diseases could be increased to some degree by EMF exposure. *Other researchers have rarely packaged their* judgments in this way, so it is hard to make comparisons. Judging by one such exercise that the DHS reviewers conducted (Neutra, 2001), reasonable scientists can have different ways of interpreting the data resulting in different degrees of certainty.

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* Although the majority of scientists assembled to prepare the NIEHS Working Group Report voted for a "possible 2B" classification for these cancers, the lay person's summary submitted by the Director of NIEHS to Congress stated: "*ELF-EMF exposure cannot* be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard." (Final Report NIH Publication 99-4493, May 1999)

The three DHS reviewers have been active in the EMF field for more than a decade and are familiar with the opinions and arguments used by the scientists in scientific meetings. Since Reviewer 1 was part of the IARC-EMF review panel and all three reviewers had some participation in the earlier parts of the NIEHS process, they also have some understanding of the process by which selected panels of these individuals arrived at a group determination about EMFs. The reviewers think there are at least two relevant differences between their process and the usual procedures followed by the other groups.

First, the DHS Guidelines require that they consider the inherent tendency of the several streams of evidence to either miss a true effect, or falsely "indict" a putative causal agent. The weight given to those streams of evidence was influenced by this consideration. The standard guidelines involve discussions of whether the adjectives "limited" or "sufficient" best fit the pattern observed in a stream of evidence, and depending on the decision one makes, simple *guidelines* of how combinations of "limited" and "sufficient" streams of evidence influence whether a "possible," "probable," or "definite" causal status is assigned. While the DHS Guidelines allow null results of animal pathology studies using one ingredient of a mixture to get little weight, the IARC rules involve a simple combination of binary judgments about the animal and epidemiological evidence. The way the DHS reviewers used the Guidelines meant that they did not let the primarily null results from the mechanistic and animal pathology streams of evidence decrease their certainty as much as seems to be the case for reviewers in other panels. The reasons for this have been explained above. Having been less deterred by the null mechanistic and animal pathology, they were also less prone to invoke unspecified confounders and bias as an explanation for the persistent, if not homogeneous, epidemiological findings for certain health endpoints.

The other reason for the discrepancies in the DHS reviewers' IARC classification choices can be traced to differences in the procedures for combining the scientists' judgments. They found several striking differences between the IARC and this evaluation processes:

- The Panel's Composition. The EMF Program's review was carried out by the EMF Program's scientific staff and not by a large panel of experts outside the agency. An outside panel, however, evaluated the document. One could criticize the DHS panel as being too small and not diverse enough, but this is standard procedure for California government agencies. The IARC followed its usual practice of convening outside experts to write drafts, discuss the drafts, and turn them over to staff to finalize. Given the spread of the scientific opinions on the EMF issue, it is safe to say that the outcome of any review is a strong function of the working group members' belief before the review takes place. (The DHS reviewers have striven to make this transparent through the elicitation of the prior beliefs and the "pro and con" discussion.) Two unbiased ways to assemble a working group would be by random selection out of a pool of "qualified" individuals or through a conscious effort to include balanced numbers of individuals known to have opposite points of view. In the first case, the definition of "qualified" could influence the verdict of any sample, and sampling variability could yield a mix of opinions that would vary from sample to sample so that different working groups could reach different conclusions. The second procedure could be an excellent solution, if the evaluation were carried out through extensive debates and discussions, with a shared desire to come to a consensus opinion irrespective of its potential social and economic consequences. This was the original approach used by IARC (Tomatis, private communication). However, the pressure to conclude the evaluation within a short period of time led to abandoning the discussion format in favor of the voting system. This leads to the next important difference.
- The Time Element: The meeting to draft the IARC-EMF monograph (June, 2001) lasted five and a half days. The vast majority of the plenary session time was dedicated to reviewing the draft chapters prepared ahead of time by designated committee members with maybe 10% of the time allowed for discussion of the rationale for reaching conclusions. Whenever a paragraph precipitated a controversial discussion, a common way out was to propose the deletion of the offending paragraph, a proposal that the time-pressured working group members were usually glad to adopt. In contrast to this process, the DHS reviewers spent innumerable hours and days, over a period of years and in consultation with independent consultants, to explain their inferences and resolve or clarify their differences.
- The Format of the Conclusion: IARC aims for a consensus conclusion. Members with more extreme views are strongly encouraged to converge on a middle of the road conclusion. In the California evaluation, if consensus could not be reached (as was the case for some endpoints), each member was allowed to express his or her personal belief. Although two of the DHS reviewers were subordinate to the third, substantial differences remained for some endpoints and are openly revealed in this evaluation.
- IARC's Voting System: The members of the working group were asked to vote separately on animal and human evidence. Although a sizable

minority of the working group believed that there was limited animal evidence indicating a possible cancer risk, their opinion was not carried past that point of the process. Since the majority regarded the animal evidence as "inadequate," when the final vote on the overall evaluation was taken, the option posed to the working group's members were the majority positions, that is, that animal evidence was inadequate and epidemiological evidence for childhood leukemia was limited. According to the guidelines, these two majority positions resulted automatically in a Group 2B classification and Class 2A or Class 1 were not even considered as options to vote on, even if individual reviewers, such as Reviewer 1, might have so voted. The published monograph does not document that the minority view had in fact a higher degree of certainty of the EMF risk than the majority view.

Somewhat similar considerations apply to the NIEHS evaluation. Although the whole process lasted eighteen months, the decision was reached over the course of a week-long meeting, followed by a vote. This meeting was preceded by a series of workshops including discussions and presentations, but not all members of the working group participated in the workshops, and most of the workshop participants were not members of the working group. Therefore, the final conclusion was still the result of a few days intensive meeting, during which much of the time was devoted to revising and finalizing the wording of the final report rather than to writing about points of controversy. The working group report did document the vote count.

Apart from procedural differences, there are also philosophical differences between the various review panels. For example, with regard to adult leukemia, the IARC's evaluation differs from the NIEHS and the California evaluation because of the way epidemiological evidence was considered. Almost all the evidence on adult leukemia comes from occupational studies. The Epidemiology subgroup at the IARC meeting regarded most of these studies as being of poor quality, with within- and between-study inconsistencies. Most of the evaluation centered on the most recent large studies (Sahl, Kelsh & Greenland, 1993), (Savitz & Loomis, 1995), and (Theriault et al., 1994), which contradicted each other. The DHS reviewers' evaluation considered the whole body of studies, residential and occupational. While they acknowledge that many of the studies have limitations, neither they, nor the IARC reviewers, have identified fatal flaws. For example, there is no evidence to suggest that the use of crude exposure assessment surrogates, while virtually certain to influence the quantitative estimate of risk and to frustrate any attempt to explore the dose-response relationship, introduced an upward bias in the reported association. On the contrary, the limitations of the studies may well be responsible for the inconsistencies between them. And while these inconsistencies do exist, they are not as common as the IARC evaluation may suggest. The Kheifets (1997) meta-analysis concludes that the body of epidemiological evidence shows a slight but statistically significant increase in risk. From a binary outcome standpoint, the studies with a relative risk estimate >1 are more than twice as numerous as those with a RR ≤ 1.

Nonetheless, where the DHS and other reviewer panels agreed to assign a "possible" carcinogen label to an EMF/disease association, it is not easy to infer if there would be agreement on a degree of certainty. According to Dr. Rice, Chief of IARC's Carcinogen Identification and Evaluation Unit (personal communication to Vincent DelPizzo), "If IARC were to say that an exposure is in Group 2A, probably carcinogenic to humans, that would mean that the evidence is just a little short of certainty that the exposure in question has actually caused human cancer. . . Group 2B is the lowest level of identifiable carcinogenic hazard in the IARC system."

Finally, it must be remembered that in DHS's EMF Program, policy recommendations were addressed separately from the risk evaluation. In some other cases, evaluations are part and parcel of a policy recommendation (they may include regulatory recommendations in the conclusion). This may make them more conservative, as it seems to be the case with IARC: "....the IARC Monographs system of carcinogenic hazard evaluations is deliberately a very conservative one. There are many carcinogenic hazards in the human environment that are very real indeed, and control of exposures to those hazards is extremely important for public health. To accomplish this, it is necessary that carcinogenic hazards be correctly identified. We must avoid misdirecting public attention to any exposure of any kind that may be perceived as a hazard, but in fact is a misplaced concern." (Dr. Jerry Rice in a letter to Vincent DelPizzo, Aug. 10, 2001). The cover letter to the NIEHS report to congress concluded with a recommendation for only "passive regulatory action" (NIEHS, 1999). The DHS's three reviewers have packaged their differing degrees of confidence about causality in a way that can be used in the decision analytic models prepared for the program. DHS has pointed out that the policy implications of this range of confidences depends on the policy framework of the decision maker: non-interventionist, utilitarian, virtual-certainty-required, or social justice. The public regulatory process will determine which one or which mixture of these frameworks will apply to govern policy. Thus the DHS risk evaluation is packaged to facilitate decision making but separates risk assessment from risk management. The fact that a reviewer may feel very certain that EMF is a risk factor for a particular disease does not imply that he or she advocates exposure mitigation.

In summary, the differences between the DHS reviewers' judgments and those of other reviewers are partly due to differences in procedure and terminology and partly due to the way those three reviewers weighed the several streams of evidence.

15 Differences Between DHS Reviewers

As noted above, the three DHS reviewers were not able to reach a consensus on all health endpoints. In this section, they explain the reasons behind their respective judgments.

15.1 Reviewer 1 (DelPizzo)

In almost all cases, Reviewer 1's posterior degree of confidence is higher than that of the other two reviewers. There are several reasons for this difference.

a) Different priors—the reviewer is generally more suspicious of man-made environmental pollutants, which have no place in the evolution process.

b) Reliance on the sign test—this reviewer has put much weight in the sign test, a simple, dichotomous test, which measures the probability of several studies erroneously reporting the existence of a risk while no risk truly exists. In many cases the test finds that this probability is extremely small, that is, the results are unlikely to be erroneous. In the reviewer's opinion, this test is particularly suitable to answer the simple question, is there a risk or not? rather than asking what the relative risk is. The results of this test are not changed if the outcome of one or more studies are partly due to bias. Some worst-case scenarios, assuming extraordinary coincidences of chance and bias acting simultaneously in the same direction, do weaken the evidence, but when a condition has been studied by many different investigators, these scenarios do not reduce Reviewer 1's belief by much.

c) Weight given to empirical results—Reviewer 1's prior was limited by the intuitive belief that the energy associated with environmental EMFs is so small that, even if these fields are potentially disruptive, the amount of disruption is insufficient to cause a biological effect. Once Reviewer 1 examined the results of in vivo and in vitro research on EMF exposure, however, he became convinced that biological EFFECTS (as distinct from PATHOLOGY) can result from exposure to levels below those which conventional knowledge considers necessary. That is, if one equates "energy" to "dose," exposure to environmental fields may be regarded as a non-negligible dose. Thus, the argument that kept Reviewer 1's prior low disappears and the possibility of a hazard, when repeatedly reported by independent epidemiological studies, becomes more credible.

15.2 Reviewer 2 (Neutra)

The fact that EMFs are the only agent that this reviewer has encountered for which there are theoretical arguments that no physiological, much less pathological, effect could be possible, did decrease Reviewer 2's prior somewhat. But physics applied to simplified models of biology were not convincing enough to make this prior credibility vanishingly small. This reviewer noted biological effects in mechanistic experiments in the thousands of mG but accepted the arguments that these were probably not relevant to effects below 100 mG. The few experiments that claimed to show an effect below 100 mG (the chick embryo studies and the confirmatory studies of Liburdy's melatonin studies) were considered highly worthy of further study, but not robust enough or free enough of alternative explanations at this point to cancel out the modest initial doubts about the energetic feasibility of residential EMFs to produce biological effects. The animal pathology studies have convinced Reviewer 2 that very-high-intensity pure 60 Hz or 50 Hz sinusoidal magnetic fields do not have a strong enough effect to produce consistent pathological effects in small numbers of the species and strains of animals selected for study. If these species of animals were to respond as humans are described to have done in the epidemiology, this was a predictable result even if pure sinusoidal 60 Hz fields were the active ingredient of the EMF mixture. Humans exposed to hundreds of mG, like electric train engineers, when compared to persons with 24-hour average exposures around 1 mG do not show relative risks consistently above 1.00 much less very high relative risks. Why would animals be expected to do so? Moreover, pure sinusoidal fields may not be a bioactive ingredient of the mixture, and the animal species chosen may not be appropriate models for humans. Reviewer 2 believes that the animal bioassay stream of evidence in this case is thus triply vulnerable to missing a true effect, and the null results do not reduce his confidence in an EMF effect much. The fact that there are epidemiological associations with several different cancer types and with other diseases that have different known risk factors does increase confidence somewhat but, without mechanistic reasons, not a great deal. Any changes from the prior were due to epidemiological evidence. Large studies likely to be free of selection bias carried a lot of weight. Many studies of different design and in different locations showing similar results also carried substantial weight, although Reviewer 2 only interpreted the sign test to indicate whether a meta-analytic or pooled association came from just a few large studies, or from a rather consistent pattern of result from many studies. Reviewer 2 did not think that any of the specific

candidate confounders or biases that had been proposed to date for explaining away the epidemiology had convincing evidence to support it. The fact that most of the associations are not much above the resolving power of epidemiological studies left open the possibility of unspecified combinations of bias, confounding, and chance having produced these associations. This kept Reviewer 2 from having an updated degree of confidence above the certainty zone of "close to the dividing line between believing and not believing" that EMFs increase the risk to some degree.

15.3 Reviewer 3 (Lee)

Reviewer 3 mainly used the human epidemiological evidence to form a posterior degree of confidence. The large number of studies showing consistent results across different study designs, study populations, and exposure assessments, as well as large, well-conducted studies with adequate power to address confounding, bias, dose response, and effects among subgroups contributed strongly in updating the prior degree of confidence. The association of EMF with several types of disease and experimental and animal evidence were minor contributions to the updating process. Specificity, visibility, analogy, and, in general, temporality did not contribute much to the posterior degree of confidence.

16 How The Degrees of Confidence and Range of Uncertainty Could be Used in Policy Analyses

Community and stakeholder policy decisions usually are made from one or more of the following ethical perspectives: "non-interference," which emphasizes individual choice and rights free from the infringement of others and of government; "social justice," which emphasizes the protection of the weak, and rights and duties; "virtual-certainty-required," where protective action is only taken when the vast majority of scientists are virtually certain that there is a problem; and the "utilitarian perspective," which emphasizes results and the most good for the most people at the least cost. Each perspective would have somewhat different requirements for the degree of confidence of causality before initiating action.

The "non-interference" perspective seeks to avoid regulatory impingement and taxes and tends to favor "right to know" warnings and voluntary solutions to problems, regardless of the degree of confidence. The "virtual-certainty-required" framework would tend to require a high degree of confidence with narrow uncertainty bounds on the part of most scientists and a high probability of harm from exposure before acting on an environmental hazard. Indeed, this perspective would favor risk-assessment methods having few false positives, even at the cost of false negatives.

The "social justice" perspective seeks to avoid even the possibility of risk, particularly if the risk and the benefit are imposed on different parties. This perspective would tend to advocate protective action at lower degrees of confidence, wider uncertainties, and lower absolute probabilities of harm given exposure. It would favor risk-assessment approaches with few false negatives, even in the face of false positives. It would focus on the added lifetime risk to the most highly exposed.

The "utilitarian cost/benefit" perspective would evaluate the policy implications of the best estimate of the degree of confidence but would explore the consequences of the lower and upper bounds of the confidence that a hazard exists. It would focus on the burden of societal disease that could be avoided by EMF mitigation. Depending on the relative prevalence of stakeholders who suffer, respectively, from false positives and false negatives, the utilitarian perspective would develop a preference for risk-assessment methodologies. The reviewers would propose that the policy integration document discuss the implications for policy arising from the range of best estimates among the three reviewers and the range of uncertainties expressed. It should also discuss where the three DHS reviewers' degrees of confidence lie in the spectrum of scientific opinion.

17 Evidence of Risk Relevant for Policymakers Mindful of Environmental Justice Issues

It is sometimes alleged that lower SES subjects are more likely to live in areas with stronger environmental EMFs. Salzberg et al. (Salzberg, Farish & DelPizzo, 1992) first explored this hypothesis and found only weak support for it. Bracken et al. (Bracken et al., 1998) reported a strong correlation between some SES indicators (women's occupations, house values) and the very high-current configuration (VHCC) wire code configuration. Hatch (Hatch et al., 2000) found no such association. Two very large data sets collected in the San Francisco Bay Area as part of the study by Lee et al. (Lee et al., 2002) found no evidence of an association between family income and measured EMF exposure. However, there was a weak association between low SES and wire code (Hristova et al., 1997). In a geographic information system (GIS) study as part of the power grid policy project, English et al. (http://www.dhs.ca.gov/ehib/ emf/ pdf/ AppendixG-GIS.PDF) examined the ethnic and income characteristics of census blocks within 500 feet of transmission lines. The proportion of black and Hispanic residents in these corridors was lower than the state average proportion. Zaffanella and Hooper (Zaffanella & Hooper, 2000) found somewhat higher magnetic fields in schools with students of lower socioeconomic status. In summary, the evidence to support the contention that the EMF exposure,

if *real*, disproportionately affects low SES subjects is not very strong, but there is some suggestive data that decision makers may consider when evaluating policy options.

18 THE EMF MIXTURE

A careful assessment of the electricity-related exposures from power lines, appliances, and occupations would reveal what amounts to a *complex mixture* including electrical and magnetic fields with their respective frequency, polarization, etc. The reviewers will call these the "aspects" of the mixture.

Each aspect varies from instant to instant to form a time-series of intensities, which can be summarized as a single number by various *summary "exposure metrics,"* which may be more or less biologically active. For example, the exposure metric of ionizing radiation that best predicts biological effects is the simple integral of the *exposure-time* series. *The exposure metric* that best predicts the effect of an antibiotic might be the integral of blood levels above some threshold. Other electricity-related correlates of proximity to power lines, *internal wiring, and* appliances are not part of the fields at all, but might be correlated with them. These include electrically charged and "sticky" air pollution particles; contact currents from stray currents, from plumbing and in the earth, and intermittent shocks. The reviewers will call these the "ingredients" of the mixture.

What aspects; ingredients, or exposure metrics, if any, should we be considering in this risk evaluation?

For a number of years, some researchers believed that if the risk increase were truly due to some component of the EMF *mixture* then this component must be something captured by the exposure-assessment surrogate known as "wire coding," consisting of classifying residences based on their *proximity to visible power lines and on the type of these* power lines. Recent new data and reanalysis of old data (Linet et al., 1997), (Greenland et al., 2000) appear to have disposed of this hypothesis convincingly. They have shown that *risk is more consistently correlated* to measured or calculated TWA magnetic field than to wire coding classification.

This does not mean that the TWA—measured by surrogates such as point-in-time or "spot" measurements, calculations using engineering models and historical line current loads and job exposure matrices—*is necessarily the true causal agent.* The units, mG or μT, that measure the magnetic field's TWA do not describe the magnetic field (and much less the electric field associated with it) any more than the units marked on the *volume dial on a stereo system* fully describe the sound coming out of the speakers.

Nevertheless, although the reviewers cannot definitely "rule in" the component(s) of interest, they can rule out some aspects of the fields that are not correlated with TWA field strength. A detailed discussion of this issue can be found in Neutra and DelPizzo (2001). Here, the reviewers include Table VII adapted from that paper, pointing out which of the more commonly proposed metrics are indeed correlated with TWA (indicated by a "• ") and those which are not (indicated by "No"):

TABLE VII. CORRELATION OR ABSENCE OF CORRELATION BETWEEN EXPOSURE METRICS AND EXPOSURE-ASSESSMENT SURROGATES

EXPOSURE METRIC TO 30-300 HZ MAGNETIC FIELDS	HIGH WIRE CODE	HIGH MEASURED FIELD	HEALTH ENDPOINT	REFERENCE
(1) TWA	•	•	•	many
(2) Length of time with constant field above a threshold	•	•		
(3) Repeated periods of elevated exposure	•	•	•	(Feychting, Forssen & Floderus, 1997), (Feychting, Pedersen & Svedberg, 1998b). (Lee & McLoed, 1998)
(4) Third harmonic	•	?	?	(Kaune, 1994b)
(5) Resonance with static field	No	No	?	(Kaune, 1994b), (Bowman, 1995)
(6) Time above a threshold	•	•	?	(von Winterfeldt & et. al., 2001)
(7) Polarization	?	?	?	(Burch et al., 2000)
(8) Transients	No	No		(Preece et al., 1999)
(9) Maximum daily exposure	•	•	•	(Li et al., 2002), (Lee et al., 2002)
(10) Average change between measurements	•	•	•	(Lee et al., 2002)
(11) Electric field	Not inside home	Not inside home	?	(Miller et al., 1996), (Coghill et al., 1996)

This table allows the reviewers, at least, to cast doubt on two metrics that are supported by mechanistic arguments, but not (or at least not consistently) by empirical data. These are 1) magnetic field transient, which can induce strong, if brief, electrical currents in the body, and 2) resonance conditions, which may facilitate energy transfer from the field to the living organism.

The table also emphasizes the difficulty of testing the hypothesis of an EMF risk by conducting experimental studies. Studies using an exposure apparatus that delivers an appropriate TWA (but not an appropriate exposure to a hypothetical aspect, ingredient, or exposure metric found in residential or occupational environments) are liable to produce false-negative results. Or they may produce positive results suggesting dose-response relationships different from those that may result from environmental fields.

Reducing TWA exposure will reduce exposure to several other metrics and reduce *any risk from TWA or the exposure metrics that are changed with it. However*, this is a sufficient but not necessary condition: if TWA is not by itself the causal factor and if we could identify and remove from the EMF mixture the component directly causally associated with the health endpoint, a subject could still be exposed to high TWA and not be at risk. Also, because the correlation coefficient between TWA and these other components of the field are modest to moderate, reducing TWA exposure would not reduce the risk proportionally to the decrease in the average field strength.

The following table compares the values of the magnetic field strength, measured by direct personal measurement or by environmental monitoring (spot or 24-hour measurements). Note that these are not data collected on the same sample, but general information gleaned from the literature (Zaffanella & Kalton, 1998), (Lee et al., 2002) and mathematical modeling.

TABLE VIII COMPARISON OF THE VALUES OF THE MAGNETIC FIELD (MG) STRENGTH MEASURED BY DIRECT PERSONAL MEASUREMENT WITH ENVIRONMENTAL MEASUREMENTS

PERCENTILE POINT OF EACH TYPE OF MEASUREMENT	TWA PERSONAL FIELD	AVERAGE SPOT HOME MEASUREMENT	MEDIAN SPOT HOME MEASUREMENT	MEDIAN 24-HOUR HOME FIELD
99	5.5	6.6	5.8	5.5
95	3.2	3	2.6	2.6
90	2.4	2.1	1.7	1.8
75	1.5	1.1	1	1
50	0.9	0.6	0.5	0.5

The personal TWA is generally higher than the environmental levels, reflecting the contribution that occasional close proximity to localized sources (appliances, wall wires, buried cables) makes to the average personal exposure. However, at the upper end of the distribution, this difference is minimal or non-existent, reflecting the fact that exposure to localized sources *is common to all subjects. These localized* sources contribute a few tenths of a mG to the personal 24-hour average (TWA).

What determines the "exposed" status of a subject in epidemiological studies (generally defined as a TWA above 2–4 mG) is usually the background environmental exposure, and that is contributed largely by home exposure (where people spend the most time). Certain occupations are an exception to this generalization because work-time exposure is so much higher than home exposure. According to Zaffanella's "1000 homes study" (Zaffanella, 1998), these background fields are due, with almost equal frequency, to proximate power lines and to grounding system fields.

Of course, this conclusion about background fields will change drastically if future research confirms the hypothesis-generating data by Lee (Lee et al., 2002) and Li (Li et al., 2002), indicating that, at least for spontaneous abortion (SAB), the true risk factor is the maximum daily exposure above 14 mG or the average field change between measurements. If maximum exposure, or one very strongly correlated to it, is the appropriate metric, then sources of localized fields (appliances, home wiring) become more important than power lines and ground currents because the latter seldom produce fields of the intensity implicated by the Lee and Li studies.

An additional difficulty that arises in this case is that personal measurements taken at the hip, as is common practice, may introduce errors that are large compared to the instrument error. This is because the field produced by a localized source shows significant variation based on which anatomical site is measured (DelPizzo, 1993),

even though some sources like power lines outside the house may produce a field at locations like the eye and the hip that are virtually identical. We also have no clear evidence by which to determine if the EMFs interact with biological systems at specific target organs. For example, there is some evidence that birds perceive geographic variations of the earth's magnetic field by means of their eyes (Graves, 1981). On the other hand, EMFs might act directly on cells in the marrow or in the uterus. Personal measurements taken at the hip might miss some exposures to the eye, but not exposures to the uterus.

It must be stressed that, although the Li (2002) and Lee (2002) studies are recent, good-quality studies with similar results, they have not yet been replicated. While meriting attention, they do not negate the wealth of data associating 24-hour average field to risk of other diseases.

19 Potential Annual Numbers of Deaths Attributable to EMFs

Two recent review articles calculated the proportion of all childhood leukemia cases that might be attributed to the rare highest residential EMF exposures. This was estimated to be around 3%. With about 100 childhood leukemia deaths per year, this would translate to about 3 deaths in California per year attributable to EMFs. The evidence does not permit similar direct calculations for the other reviewed conditions. However, suppose that only 1% of the conditions that were considered in this evaluation (minus those that the three reviewers "strongly believed" were not caused by EMFs) could be attributed to EMF exposure. The numbers of attributable cases could still be in the hundreds per year and comparable to the theoretical burden of ill health that has motivated other environmental regulation (di Bartolomeis, 1994). The annual California deaths from each of these conditions are shown in Table IX. The reader can apply 1% to these numbers to verify the assertion in the previous sentence.

Table IX. 1998 Yearly California Deaths (some fraction of which might be affected by EMFs) *

AGE GROUP	CHILD LEUK.	ADULT LEUK.	CHILD BRAIN	ADULT BRAIN	MALE BREAST	FEMALE BREAST	SPONT. ABORT.*	ALS	ALZ-HEIMER	SUICIDE	ACUTE M.I.
0-19	99	0	79	0	0	0	11,000	0	0	171	2
29 Plus	0	1888	0	1294	30	4095	49,000	434	320	3044	17,236

* From http://www.ehdp.com/vn/ro/av/cau1/eq1/index.htm

* Note: many would not consider spontaneous abortion as serious as the death of a child or adult.

20 Potential Added Lifetime Risk from High Exposure

Since epidemiology is a blunt research instrument, the theoretical lifetime individual risk that derives from any agent that has an epidemiologically detectable effect will be automatically greater than the lifetime risk of 1/100,000 that triggers many regulatory processes. This means most of the epidemiological associations examined in this document could clearly be of regulatory concern if real.

That being said, with the exception of miscarriage, the theoretical lifetime risks from the highest EMF exposures are such that, depending on the disease and assuming relative risks ranging from 1.2 to 2.0, 93% to 99.9% of even highly exposed individuals would escape contracting the non-miscarriage health conditions studied.

These insights are illustrated in Table X below.

TABLE X. ADDED LIFETIME RISK IMPLIED BY RELATIVE RISKS OF 1.2 OR 2.0 FOR RARE AND COMMON DISEASES

ANNUAL INCIDENCE	DISEASES IN CATEGORY	ADDED ANNUAL RISK FROM: RR =1.2; RR= 2.0	ADDED LIFETIME RISK FROM: RR = 1.2, RR = 2.0	LIFETIME CHANCE OF ESCAPING DISEASE AFTER EXPOSURE
1/100,000	ALS, Male Breast Cancer	0.2/100,000 ; 1/100,000	1.4/10,000; 7/10,000	99.99%; 99.93%
5/100,000	Child Leukemia	1/100,000; 5/100,000	2/10,000; 10/10,000	99.98%; 99.9%
10/100,000	Suicide, Adult Brain, & Leuk.	2/100,000; 10/100,000	14/10,000; 70/10,000	99.9%; 98.3%
100/100,000	Acute Myocardial Infarction	20/100,000; 100/100,000	1.4%; 6.8%	98.6%; 93.2%
1%	Alzheimer's	0.2%; 1%	NA (late onset)	NA
10%	Miscarriage	2%; 10%	NA (occurs during pregnancy)	NA

Note: RR = risk ratio; NA = not applicable

Two new epidemiology studies (Li et al., 2002), (Lee et al., 2002) suggest that a substantial proportion of miscarriages might be caused by EMFs. Miscarriages are common in any case (about 10 out of 100 pregnancies) and the theoretical added risk for an EMF-exposed pregnant woman may be an additional 10 out of 100 pregnancies according to these two studies. If true, this could clearly be of personal and regulatory concern. However, the type of EMF exposure implicated by the new epidemiological studies (short, very high exposures) probably come primarily from being very close to appliances and indoor wiring, and only rarely from power lines. Seventy-five percent of the women in the studies had at least one of these exposures during a day, and even one exposure a day, if typically experienced during pregnancy, seemed to increase the risk of miscarriage. Nonetheless, the vast majority of pregnant women with such exposures did NOT miscarry.

21 POLICY-RELEVANT AREAS FOR FURTHER RESEARCH

One of the major impediments to evaluating the potential bioactivity of a complex mixture is identifying the bioactive components of that mixture. This usually requires finding some kind of bioassay with which to assess the mixture and then successive fractions of it. While some epidemiologists have attempted to evaluate the effects of different aspects of the EMF mixture and some exposure analysts have attempted to characterize the occurrence and intercorrelation of its aspects, important policy-relevant questions still remain.

Experimentalists have rarely used the mixture as it occurs in real life and have focused instead on one or the other aspect of the mixture, usually pure sinusoidal 60 Hz fields at intensities far above those found in residential or blue collar occupational environments. Deeply ingrained experimental research styles and an orientation to explaining mechanisms rather than describing phenomena has meant that investigator-initiated research and even programs that attempted to guide research have rarely been characterized by progressively refined descriptions of dose-response relationships to produce stronger bioeffects.

This has been compounded by the expectation of a quick resolution of the question by those who fund research, as was the case with the New York State program of the mid-1980s, the current California Program, and the recent five year federal EMF–RAPID program. As was discovered after President Nixon's "War on Cancer" in the early 1970s, research progresses slowly and in successive multi-year research cycles, with the results of each cycle governing the direction of the next. It would not be surprising if it took four more five-year research cycles to clarify the EMF issue.

This means that if one were serious about clarifying this issue there would need to be a long-term commitment to steady research funding and funding for intermittent assessments of the state of the science and research directions. Most research peer review groups would favor research where a clear bioeffect was present and credible alternative mechanisms were being explored. Those situations tend to have

a high yield of early definitive results, and such results lead to continued research funding, publications, and research career advancement. The EMF area does not fit this description and from this perspective would receive a low priority for funding from the usual peer review study sections. Indeed, prominent researchers who doubt that there are any bioeffects, much less epidemiological effects, from the residential and occupational EMF mixture, feel there is nothing to find and have recommended that no more funding for this area be provided (Park, 1992).

Clearly the three DHS reviewers disagree with the assessment of the evidence to date and see a number of research areas which are worth pursuing that could influence and focus exposure avoidance strategies, if any. The cost effectiveness of further research has been a topic of the program's policy analysis and will be discussed at greater length in our policy integration document. The cost/benefit analysis of EMF research suggests that there is so much at stake in choosing between "expensive," "inexpensive," and "no mitigation" that more research funding can be easily justified. (http://www.dhs.ca.gov/ehib/emf/pdf/Chapter09-ValueofInformation.pdf)

The highest initial priorities for the reviewers would be to carry out exposure studies in residential settings and the workplace to see if purported aspects of the EMF mixture that would require different mitigation strategies are correlated with magnetic field exposure and could therefore explain their apparent effect. Such aspects include sudden exposures to the 60 Hz fields, such as micro-shocks, stray ground currents, and charged air pollutants. Such exposure studies would make it possible to reanalyze some of the existing worker cohorts to determine if these aspects are associated with diseases.

Rather than further pursuing new studies of rare diseases with long incubation periods, further studies of the more common conditions in which EMFs might have shorter induction periods, such as spontaneous abortion, acute myocardial infarction, and suicide should be given priority. These would be more relevant to a utilitarian policymaker.

On the experimental front, the reviewers suggest giving priority to finding reliable bioeffects below 100 mG and to carefully exploring dose-response relationships and then mechanisms. The balance between investigator-initiated and programmed research, as well as the guidelines that will be used for interpreting results, need to be carefully considered.

Energy Conservation Council of Pennsylvania Surrebuttal Statement No. 2
Witness: Robert Q. Hanham

Pgh DK
A-110172

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

In re: Application of Trans-Allegheny Interstate Line Company	:	Docket Nos. A-110172, A_110172F0002-F0004 and G-00071229

WRITTEN SURREBUTTAL OF
ROBERT Q. HANHAM

Q. STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Robert Q. Hanham and my work address is Department of Geology and Geography, Box 6300, West Virginia University, Morgantown, WV 25506.

Q. WHO ARE YOU EMPLOYED BY?

A. I am an Associate Professor of Geography at West Virginia University.

Q. HAVE YOU PREVIOUSLY SUBMITTED DIRECT TESTIMONY IN THIS PROCEEDING ON BEHALF OF ENERGY CONSERVATION COUNCIL OF PENNSYLVANIA?

A. Yes. My direct testimony was previously submitted in this proceeding as ECC Statement No. 2.

Q. PLEASE DESCRIBE THE PURPOSE OF YOUR SURREBUTTAL.

A. My surrebuttal addresses the uneven impacts that the TrAIL Project imposes on Western Pennsylvania -- including Washington and Greene Counties, Francis R. Chiappetta's and William H. Bailey's attempts to diminish those impacts, and Bailey's failure to conduct an adequate peer review.

Q. DOES THE PRINCIPAL FOCUS OF THE TRAIL PROJECT BENEFIT WESTERN PENNSYLVANIA AND WASHINGTON AND GREENE COUNTIES, IN PARTICULAR?

A. No. As previously testified, the Project focuses principally on the transmittal of electrical generation to the points East -- including Loudoun County. Hanham Direct at 3:14-14:4. TrAILCo represents that the precise need for the Project relates to spurring "significant economic growth" in the Mid-Atlantic and Northern Virginia areas. TrAILCo Statement No. 3 at 22:13-18 (Testimony Steven R. Herling).

Q. PLEASE EXPLAIN WHY THE TRAIL PROJECT BENEFITS POINTS EAST?

A. The Project allegedly addresses consumer demand. TrAILCo states "consumer demand" in the mid-Atlantic ("areas along the Atlantic seaboard from the District of Columbia to Northern New Jersey") and northern Virginia is the primary factor causing "electrical need for the TrAIL project." TrAILCo Statement No. 4 at 16:19-19:9 (Testimony Scott W. Gass). TrAILCo claims that the existence of that demand is supported by load growth in the northern Virginia area of 40% in Dominion Virginia Power's service territory and over 60% in Allegheny Power's service territory. *Id.* at 19:13-17.

TrAILCo defines consumer demand to consist of two components: (1) the number of consumers and (2) use per consumer. *Id.* at 19:3-9. The census data referenced in my previous testimony demonstrates that increased consumer demand exists, if at all, outside the Commonwealth of Pennsylvania. As I point out, that the census data indicates the population of Loudoun County has grown by an estimated 95,000 from 2000 to 2006. *See* Hanham 3:23-4:9 and Exhibit RQH-3. Neither Washington County nor Greene County have experienced even remotely similar growth.

Q. DOES THE PROJECT PROVIDE ANY TANGIBLE BENEFIT TO WASHINGTON AND GREENE COUNTIES?

A. No. TrAILCo articulates the need for the Project, in part, to alleviate so-called "load pockets." Scott Gass testified that "load pockets" are created where a high use area has too little local generation and has to import power from neighboring areas. TrAILCo Statement No. 4 at 9:14-10:6 (Testimony Scott W. Gass). Such load pockets typically occur in urban areas. *Id.*

Washington and Greene Counties are primarily rural areas and, according to TrAILCo's own definitions, are not likely to generate load pockets. Moreover, from 2000-2006, the population of Washington and Greene Counties, Pennsylvania apparently grew only by a combined 3,200. *See* Exhibit RQH-2. By contrast, Loudoun County, an urban suburb of the District of Columbia, experienced a large population growth in the past six years. Gass, himself, confirms that "load pockets" in the Northern Virginia area (not Pennsylvania) drive the Project.

Based on prior testimony of TrAILCo's witnesses, TrAILCo's own documents, my research, and the testimony of George Loehr and Peter Lanzalotta, I conclude that the Project adds no real or sustained value to Washington and Greene Counties. This conclusion is particularly true given the uneven impacts the Project imposes on Washington and Greene Counties and Pennsylvania as a whole.

Q. WHAT UNEVEN IMPACTS DOES THE PROJECT POSE TO WASHINGTON AND GREENE COUNTIES AND WESTERN PENNSYLVANIA?

A. Consistent with my prior testimony, Washington and Greene Counties and Western Pennsylvania will suffer markedly more detrimental impacts than the Mid-Atlantic and Northern Virginia areas without receiving any corresponding benefit. Hanham Direct at 3:4-14:4. These uneven impacts include (a) the direct taking of citizens' property in Washington and Greene Counties for the right of way, (b) the diminution in value of the residual property owned by the citizens, (c) the physical construction of the 500 KV and 138 KV lines and attendant structures, (d) the use of potentially harmful processes to maintain the right of way, (e) increased pollution, and (f) increased exposure to potential health risks. Accordingly, the value of communities in Western Pennsylvania

-- particularly Greene and Washington Counties -- are going to be reduced while the value of communities on the east coast will be raised by the Project.

Q. WHAT DATA ARE RELEVANT TO DETERMINING UNEVEN IMPACTS?

A. In addition to evaluating the benefits, an assessment of the Project under uneven economic development theory requires inquiry into the potential negative impacts of construction. A myriad of data may assist in the analysis including governmental reports, public input, independent research data, and available industry data. Because the Project implicates both transmission and generation, the potential impacts include, but are not limited to, (a) increased pollution, (b) diminution of property values and (c) increased health risks.

Q. IN ASSESSING POLLUTION IMPACTS, WHAT DATA HAVE YOU LOOKED AT?

A. As noted in my direct testimony, I examined, among other things, the Intergovernmental Panel on Climate Change, the Environmental Protection Agency's Toxic Release Inventory (2005), and the Sierra Club's report from its Clean Air Committee. *See* Hanham Direct at 6:12-8:17 & RQH-4, RQH-9, & RQH-10. The Sierra Club's report, submitted in the Public Input Hearings, cites The American Lung Association's State of Air 2007 report and Mercury Deposition in Pennsylvania 2005 Status Report authored by the Environmental Resources Research Institute associated with Pennsylvania State University. Additionally, I have reviewed the Carbon Dioxide Emissions reports covering Allegheny Power plants. *See* Allegheny Power Plant Spreadsheet RQH-12, and TrAILCo's Responses and Produced Documents to ECC's Interrogatories I-35 and I-63.

The proximity of Western Pennsylvania, including Washington and Greene Counties, to point sources of emissions in comparison to the proximity of Northern Virginia, including Loudon County, to the same sources is readily discernable. The available data indicates that Western Pennsylvania already suffers greater environmental impacts than points East benefiting from the Project. Moreover, TrAILCo's own documents suggest that additional environmental impacts -- in the form of new coal-fired plants -- may occur in the West further impacting Western Pennsylvania.

Q. IN REACHING YOUR CONCLUSION THAT PROPERTY VALUES WILL BE DIMINISHED, WHAT DID YOU CONSIDER?

A. Among other things, I considered the documents and testimony introduced in the Public Input Hearings. That evidence explored the potential impact of high voltage lines on the lives of affected citizens in Washington and Greene Counties and Western Pennsylvania. That evidence also included articles written from the vantage point of certified real estate appraisers. The articles concerned relative values of property encumbered by high voltage power lines. These articles indicated that high voltage power lines do diminish value. Additionally, I considered the fact that TrAILCo has directly approached land owners within the proposed corridor and offered monetary consideration (the so-called Damages Release) to proceed with the Project. The evidence supports the reasonable conclusion that real property in Washington and Greene Counties will be diminished in value as result of the Project.

Q. HAVE YOU REVIEWED THE REBUTTAL TESTIMONY OF FRANCIS R. CHIAPPETTA?

A. Yes, I have.

Q. WHAT IS THE APPARENT PURPOSE OF CHIAPPETTA'S TESTIMONY?

A. Chiappetta attempts to attack my reasonable conclusion that the Project adversely impacts the value of certain real property in Washington and Greene Counties.

Q. DOES THE TESTIMONY OF FRANCIS R. CHIAPPETTA ALTER YOUR CONCLUSIONS?

A. No. Chiappetta fails to identify any prior experience in valuating real property encumbered by high voltage power lines. TrAILCo Statement No. R-17 (Testimony of Chiappetta). Moreover, Chiappetta did not conduct individual appraisals of any real property impacted by the Project. *Id.* at 6:2-5. As such, Chiappetta provides no direct evidence supporting his conclusions and his stated conclusions are directly contradicted by TrAILCo's own actions.

Additionally, to the extent Chiappetta attempts to peer review the articles raised in the Public Input Hearings, his peer review methodology is unacceptable. At best, Chiappetta confines his comments merely to one identified factor impacting valuation -- visual impairment. *See id.* at 18-21-20:3. However, the articles identify additional factors such as EMFs that negatively impacted the value of real property encumbered by high voltage power-lines. Chiappetta omits any discussion of EMFs in his review.

Q. HAVE YOU REVIEWED WILLIAM H. BAILEY'S REBUTTAL STATEMENT?

A. Yes, I have.

Q. WHAT IS YOUR UNDERSTANDING OF THE PURPOSE OF BAILEY'S STATEMENT?

A. To be honest, it was not really any different from his initial testimony. Basically, he was recycling his argument that EMFs pose little or no risk to human health. The only real difference was his resort to personal attacks.

Q. HAS BAILEY IDENTIFIED ANY AUTHORITATIVE BODY THAT CONCLUSIVELY STATES EMFS POSE NO HEALTH RISKS?

A. No. To be clear, Bailey, as he must, concedes that the scientific community has not ruled out EMFs as posing a human health risk. Indeed, the organizations upon which he relies – including the IARC -- all currently classify EMFs as being possibly carcinogenic. That classification is principally due to several epidemiological studies, documenting a statistically significant increase of childhood Leukemia cases in populations living near high voltage power lines. The scientific community also has not fully ruled the role EMFs may play either alone or in tandem with other factors in the development or progression of other diseases.

Q. SINCE THE NIEHS REPORT ISSUED IN 1999, ARE THERE OTHER STUDIES DEMONSTRATING A HEIGHTENED CARCINOGENIC RISK POSED BY HIGH VOLTAGE POWER LINES?

A. Yes. Each of the following articles are examples of studies that discuss the heightened risk of childhood leukemia posed by exposure to EMFs associated with high voltage power lines.

1. Ilhan G., Karakus S., and Andic N., *Risk Factors and Primary Prevention of Acute Leukemia*, ASIAN PAC. J. CANCER PREV. 2006 Oct-Dec; 7 (4):515-7.

2. Draper G., Vincent T., Kroll ME, Swanson J., *Childhood Cancer in Relation to Distance From High Voltage Power Lines in England and Wales: A Case Control Study*; BRITISH MEDICAL JOURNAL 2005; 330 (7503):1290.

3. Bianchi N., Crosignani P., Rovelli A. Tittarelli A., Carnelli CA, Rossitto F., Vanelli U., Porro E., Berrino F., *Overhead Electricity Power Lines and*

Childhood Leukemia: A Registry-Based, Case-Control Study, TUMORI 2000 May-June 86(s):195-8.

Q. ARE YOU QUALIFIED TO CRITIQUE THE METHODOLOGY BAILEY USES IN PEER REVIEWING THE CDHS REPORT?

A. Absolutely. Bailey is not presenting EMF research. Bailey is attempting to peer review a scientific study for litigation purposes. As a professor with 30 years of experience, I am well qualified to address the appropriate methodology to employ while peer reviewing an article. My prior criticisms of Bailey demonstrate that Bailey is not conducting an independent and neutral assessment of the CHDS report. Here, Bailey functions as an advocate, not a scientist, for the industry.

Q. WHAT DO YOU MEAN BY THAT?

A. Bailey is a paid consultant employed by Exponent and hired by the power industry, here TrAILCo, to defend its interests.

Q. DO YOU HAVE ADDITIONAL CRITIQUES OF BAILEY'S METHODOLOGY?

A. Yes. Bailey relies on the processes of the IARC, ICNIRP, and WHO for researching and reporting EMFs, suggesting that such processes are more valuable because they are derived from allegedly independent, multidisciplinary teams. My research uncovered a very interesting article by Don Maisch titled "*Conflict of Interest and Bias in Health Advisory Committees: A Case Study of the WHO's Electromagnetic Field (EMF) Task Group*" published in the JOURNAL OF THE AUSTRALASIAN COLLEGE OF NUTRITIONAL AND ENVIRONMENTAL MEDICINE in 2006. *See* RQH-13. This article examines the undue influence of the power industry in the WHO's advisory committees on EMFs and health, thereby undermining the impartiality of the exposure guidelines and scientific

advice given by those committees. The article also identifies the same conflict of interests existing in the ICNIRP.

According to Maisch, the "WHO task group writing a new Environmental Health Criteria (EHC) document on power frequency EMFs included... representatives from the electric utilities, or organizations with close ties with the industry." According to Maisch, among persons invited to weigh in on the new EHC document were representatives of several utility companies from around the world, including Exponent. Maisch concludes his article by saying that "to stack the WHO EHC task group...with representatives of the power industry...can only be construed as being aimed at ensuring that industry involvement...will bias ...risk assessment for power frequency exposure limits." Bailey, himself, participated in the ICNIRP and IARC process.

Q. DOES BAILEY'S DIRECT PARTICIPATION AND THE POWER INDUSTRIES' OVERALL PARTICIPATION IN THE IARC, ICNIRP, AND WHO PROCESSES CALL INTO QUESTION THE VALIDITY OF THOSE PROCESSES?

A. Yes. In academia, "independent research" usually refers to research developed without influence of industry interests. Bailey is an industry consultant and his prior support of the power industry is well known. Dr. Bailey's mere participation in the ICNIRP/IARC processes and the power industry's alleged participation in the WHO process calls into question the independence of such processes.

Q. DO YOU TAKE ISSUE WITH SPECIFIC STATEMENTS IN BAILEY'S REBUTTAL TESTIMONY?

A. Yes, several.

- Page 9 (lines 15-19) Bailey says that "it is obvious that persons would have no reason to spend long periods of...time on...or near the right-of-way because...the proposed route would pass through a sparsely populated area." Of course, *sparsely populated does not* equal unpopulated. Many affected people actually live or work on or near the right-of-way, so they do have reason to be there. Additionally, some affected persons own live stock or other animals that utilize the same property.

- Page 10 (lines 1-12): Bailey defends his statement that persons would be largely shielded from the electric field...by intervening trees (and) shrubbery. A right-of-way with a high voltage transmission line will be totally cleared of trees and vegetation, which means that people will not "be largely shielded."

- Page 12 (lines 8-23): Bailey addresses my critique of his conclusions based on the IARC and NIEHS reviews given my reading of the CDHS review. He states that my "knowledge...appears to be limited to his reading of the Executive Summary of their report." That assumption is wrong. I read the whole thing -- a painful experience because it is about 400 pages. He then goes on to say that I confuse "the presence of a statistical association between magnetic fields and childhood leukemia with proof of a causal relationship." Nowhere do I link statistical association and proof of a causal relationship in my testimony. Bailey apparently misreads my testimony at page 11 (lines 16-18). The word 'proof' is not in that sentence. I have taught advanced statistical methods to graduate students for 34 years, and I know only too well the fallacy of that connection. I would never link statistical association and proof of a causal relationship. It is quite clear that there are no grounds for saying that statistical association is proof of a causal link, just as there is no basis for arguing that animal experimentation is proof of a causal link.

- Pages 18-19: Dr Bailey addresses my critique of his reliance on animal experiments. In his defense, he states that "[t]he value of animal studies in human health risk is undisputed." Of course, debate does exist over the utility of animal experimentation.

- Page 21: Bailey addresses my critique of the process followed by IARC. He says that I have "erroneously described the process used by IARC" and that "contrary to Dr Hanham's description, the IARC Working Group did not use a 'simple binary response (yes or no) in evaluating studies (or simply give) a majority opinion (or draft the report) over five days." My description derived from the CDHS report -- one of whose authors was a member of the IARC panel.

Q. DOES BAILEY'S TESTIMONY CHANGE YOUR OPINION ON UNEVEN HEALTH IMPACTS?

A. No. As demonstrated, Western Pennsylvania fails to derive a benefit from the Project. The Project, however, does impose potential health risks on citizens of Washington and Greene Counties. If there is no demonstrable need for such lines, the imposition of even the slightest risk is unreasonable.

Q. DO YOU HAVE AN OPINION ON THE WEIGHT THE COMMISSION SHOULD AFFORD YOUR TESTIMONY OR BAILEY'S TESTIMONY?

A. Actually no. I trust that the Commission is quite capable of determining the relative weight evidence has in this proceeding without the burden of me weighing in on that determination. That said, Bailey's Rebuttal testimony submitted by TrAILCo fails to rebut or address my core opinions.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

plant_id	parentcomp_id	company_id	name	carbon_2000	carbon_2007
17024	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	HARRISON	14400000	14200000
17152	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	HATFIELDS FERRY	9043293	8958911
13847	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	FORT MARTIN	7390642	7328248
35027	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	PLEASANTS	6698923	6721762
2075	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	ARMSTRONG	2123367	2099231
28811	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	MITCHELL (PA)	1506386	1500480
853	ALLEGHENY ENERGY INC	MONONGAHELA POWER CO	ALBRIGHT	1219076	1200372
42832	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	SPRINGDALE AESC	43241	686426
49869	ALLEGHENY ENERGY INC	MONONGAHELA POWER CO	WILLOW ISLAND	604176.3125	597188.125
38266	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	RP SMITH	406244.5	400652.1875
37692	ALLEGHENY ENERGY INC	MONONGAHELA POWER CO	RIVESVILLE	233816.5938	229735.5938
14619	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	GANS	43241	52493.8906
16280	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	GUILFORD TOWNSHIP	0	52493.8906
18900	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	HUNLOCK CREEK AESC	31099.0098	38119.9102
6083	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	BUCHANAN COUNTY	0	23003.6895
42833	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	SPRINGDALE WPP	1051.334	15788.7803
41081	ALLEGHENY ENERGY INC	GREEN VALLEY HYDRO LLC	SHENANDOAH (VA)	0	0
49062	ALLEGHENY ENERGY INC	GREEN VALLEY HYDRO LLC	WARREN (VA)	0	0
10152	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	DAM NUMBER 5	0	0
24244	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	LAKE LYNN	0	0
26325	ALLEGHENY ENERGY INC	GREEN VALLEY HYDRO LLC	LURAY	0	0
28586	ALLEGHENY ENERGY INC	ALLEGHENY ENERGY SUPPLY CO LLC	MILLVILLE (WV)	0	0
31140	ALLEGHENY ENERGY INC	GREEN VALLEY HYDRO LLC	NEWPORT (VA)	0	0
TOTAL				43744556.75	44104906.07

plant_id	carbon_nextdecade	energy_2000	energy_2007	energy_nextdecade	intensity_2000	intensity_2007	intensity_nextdecade	state
17024	14200000	13000000	12900000	12900000	2206.4319	2209.0439	2209.0439	West Virginia
17152	8958911	8434493	8344702	8344702	2144.3601	2147.209	2147.209	Pennsylvania
13847	7328248	7669555	7595337	7595337	1927.267	1929.67	1929.67	West Virginia
35027	6721762	6043370	6063039	6063039	2216.949	2217.292	2217.292	West Virginia
2075	2099231	2108421	2081295	2081295	2014.177	2017.236	2017.236	Pennsylvania
28811	1500480	1456223	1449315	1449315	2068.895	2070.6069	2070.6069	Pennsylvania
853	1200372	979551.375	962704.125	962704.125	2489.05	2493.751	2493.751	West Virginia
42832	686426	60320.7109	1408156	1408156	1433.703	974.9289	974.9289	Pennsylvania
49869	597188.125	517147.3125	510381.1875	510381.1875	2336.573	2340.165	2340.165	West Virginia
38266	400652.1875	350690.8125	345261.9062	345261.9062	2316.824	2320.8601	2320.8601	Maryland
37692	229735.5938	172074.5938	168719.0938	168719.0938	2717.6179	2723.292	2723.292	West Virginia
14619	52493.8906	60320.7109	74280.1328	74280.1328	1433.703	1413.403	1413.403	Pennsylvania
16280	52493.8906	0	74280.1328	74280.1328	0	1413.403	1413.403	Pennsylvania
18900	38119.9102	28876.7695	35930.6992	35930.6992	2153.9121	2121.8569	2121.8569	Pennsylvania
6083	23003.6895	0	38229.5195	38229.5195	0	1203.452	1203.452	Virginia
42833	15788.7803	1278.083	24603.6191	24603.6191	1645.174	1283.452	1283.452	Pennsylvania
41081	0	2475.7671	2413.749	2413.749	0	0	0	Virginia
49062	0	3848.6399	3752.231	3752.231	0	0	0	Virginia
10152	0	3216.7739	3136.1931	3136.1931	0	0	0	West Virginia
24244	0	160347.5938	156330.9062	156330.9062	0	0	0	Pennsylvania
26325	0	7866.1592	7669.1089	7669.1089	0	0	0	Virginia
28586	0	8156.8188	7952.4888	7952.4888	0	0	0	West Virginia
31140	0	6896.8052	6724.0381	6724.0381	0	0	0	Virginia
TOTAL	44104906.07							

plant_id	city_name	metroarea	county	congdist	zip	latitude	longitude
17024	Haywood		Harrison	Alan Mollohan	26366	39.3814	-80.3362
17152	Masontown	Pittsburgh	Fayette	John Murtha	15461	39.8153	-79.8735
13847	Maidsville		Monongalia	Alan Mollohan	26541	39.7076	-80.0561
35027	Belmont		Pleasants	Alan Mollohan	26134	39.3518	-81.2939
2075	Kittanning		Armstrong	Bill Shuster	16201	40.8196	-79.4288
28811	New Eagle	Pittsburgh	Washington	John Murtha	15067	40.2059	-79.9534
853	Albright		Preston	Alan Mollohan	26519	39.5676	-79.6538
42832	Springdale	Pittsburgh	Allegheny	Jason Altmire	15144	40.5496	-79.7839
49869	Belmont		Pleasants	Alan Mollohan	26134	39.3518	-81.2939
38266	Williamsport	Hagerstown	Washington	Roscoe Bartlett	21795	39.569	-77.8139
37692	Rivesville		Marion	Alan Mollohan	26588	39.5777	-80.1451
14619	Gans	Pittsburgh	Fayette	Bill Shuster	15439	39.7428	-79.8246
16280	Marion		Franklin	Bill Shuster	17235	39.8575	-77.6987
18900	Hunlock Creek	Scranton--Wilkes-Barre--Hazleton	Luzerne	Tim Holden	18621	41.247	-76.089
6083	Oakwood		Buchanan	Rick Boucher	24631	37.2148	-81.9825
42833	Springdale	Pittsburgh	Allegheny	Jason Altmire	15144	40.5496	-79.7839
41081	0		Page	Bob Goodlatte	0	0	0
49062	Warren	Washington, DC-MD-VA-WV	Warren	Bob Goodlatte	0	0	0
10152	Hedgesville		Berkeley	Shelley Capito	0	0	0
24244	Lake Lynn	Pittsburgh	Fayette	Bill Shuster	15451	39.7473	-79.8399
26325	Luray		Page	Eric Cantor	22835	38.6496	-78.431
28586	0		Jefferson	Shelley Capito	0	0	0
31140	Newport		Giles	Rick Boucher	24128	37.3126	-80.5117
TOTAL							

J. Aust. Coll. Nutr. & Env. Med. Vol. 25 No. 1 (April 2006) pages 15-17

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Conflict of Interest & Bias in Health Advisory Committees: A case study of the WHO's Electromagnetic Field (EMF) Task Group

Don Maisch
EMFacts Information Service

... a number of independent researchers were involved in the preparation and review of the draft, but it was "highly unusual, if not unprecedented, for a WHO health document to be reviewed by so many with such strong ties to the affected industry"[13]

Introduction

The potential problem of conflicts-of-interest biasing outcomes in papers submitted to bio-medical journals, including papers published in journals by expert advisory bodies, was an issue addressed by the International Committee of Medical Journal Editors in November 2003. To quote from their *"Uniform Requirements"*:

"Conflict of interest exists when an author (or the author's institution), reviewer, or editor has financial or personal relationships that inappropriately influence (bias) his or her actions. . . The potential for conflict of interest can exist whether or not an individual believes that the relationship affects his or her scientific judgement. Financial relationships . . . are the most easily identifiable conflicts of interest and the most likely to undermine the credibility of the journal, the authors, and of science itself."[1]

This paper briefly examines this problem , using recent actions taken by the World Health Organisation's (WHO) International EMF Project and the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

In both organisations the case is presented that maintaining independence from industry vested interests is essential for maintaining scientific objectivity and credibility in giving expert advice on public health matters.

At the May 2001 Australian Senate Inquiry into Electromagnetic Radiation,Michael Repacholi, head of the WHO's International EMF Project, informed the Senate Committee that the WHO had a firm policy against industry involvement in its processes. To quote:

"The World Health Organization does not allow industry to participate in either standard setting or in health risk assessment. The WHO takes the view that there cannot be industry representation on standard setting working groups. There cannot be someone on the working group who is having an influence on health effects for an industry when they derive benefit from that industry."[2]

ICNIRP clearly states on its website that all commission members are independent experts in their respective scientific disciplines and do not represent either their countries or institutes and specifically they cannot be employed by industry. In order to maintain this independence from industry or other vested interests it is stated:

"Members are reminded frequently of the need to declare any interests detrimental to ICNIRP's status as an independent advisory body. . . ICNIRP also does not accept funding from industry."[3]

These requirements were established so that ICNIRP's credibility of its advice and guidelines cannot be said to be influenced or biased by industry vested interests. Dr Ken Joyner, from Motorola, stressed the independence of ICNIRP from industry at the Australian Senate Inquiry into Electromagnetic Radiation in May 2001. Joyner stated:

"If you want to look at one standards body that has specifically excluded any industry representatives, there is the ICNIRP body. You cannot be a member of the ICNIRP if you are part of industry. They exclude you from that process."[4]

The ICNIRP website also explains that the scientific reviews carried out by ICNIRP members are combined with risk assessments done by WHO International EMF Project working groups with the resultant being the publication of ICNIRP's EMF exposure guidelines. Therefore the claim that ICNIRP's scientific advice is value-free from industry influence must also include the same requirement for any WHO risk assessment task group. That was what Repacholi stated to the Australian Senate Committee in May 2001 (as previously quoted).

"There cannot be someone on the working group who is having an influence on health effects for an industry when they derive benefit from that industry."

The close working relationship between ICNIRP and the WHO's EMF Task Group evaluating power frequency research is seen in the makeup of the membership of the Task Group. Out of the 20 members from 17 countries [5], we have Paolo Vecchia, the current ICNIRP Chairman, Anders Ahlbon, Larry Anderson, Rudiger Matthes as members of ICNIRP's main commission, with Ahlbon also on ICNIRP's Standing Committee on Epidemiology. Other ICNIRP Standing Committee members include Christoffer Johansen, Jukka Juutilainen, Alasdair McKinlay and Zhengping Xu. Eric van Rongen is a consulting expert for ICNIRP. In addition, Michael Repacholi, head of the WHO's

International EMF Project, is also Chairman Emeritis of ICNIRP.[6]

Including Repacholi, half of the official members of the WHO task group are also members of ICNIRP, so it is obvious that there are no secrets between ICNIRP and the Task Group.

Industry influence endemic in the decision making process

As reported by the New York based publication, *Microwave News*, on October 1, 2005, the 20 member WHO Task Group writing a new Environmental Health Criteria (EHC) document on power frequency EMFs included, at the request of Repacholi, repre-sentatives from the electrical utilities, or organisations with close ties with the industry. Their task was to both assist in writing the initial draft and review the completed draft.[7] This is in clear conflict with what Repacholi stated in his testimony in the May 2001 Australian Senate Inquiry hearings. To quote again: *"There cannot be someone on the working group who is having an influence on health effects for an industry when they derive benefit from that industry."*

One of the central authors of the draft, and member of the EHC Task Group, Leeka Kheifets, was a former WHO assistant to Michael Repacholi. She disclosed in Sept. 2005 in a letter (declaring any potential conflicts of interest) to the British Medical Journal that she *"works with the Electric Power Research Institute... and consults with utilities."*[8] Other power industry representatives who assisted Kheifets in preparing the draft were Gabor Mezei, from the EPRI, Jack Sahl from Southern California Edison (USA), and Jack Swanson from the National Grid (UK). When Repacholi sent a draft of the EHC out for review in early July 2005, the reviewers included representatives from the power industry bodies: The Federation of Electric Power Companies of Japan, Pacificorp (USA), Hydro-Quebec (Canada), the Utility Health Sciences Group (USA) and Exponent Inc (USA).[9] The question of liability must have also been on the agenda, as Exponent has described its business activities as follows:

"Exponent serves clients in automotive, aviation, chemical, construction, energy, government, health, insurance, manufacturing, technology and other sectors of the economy. Many of our engagements are initiated by lawyers or insurance companies, whose clients anticipate, or are engaged in, litigation over an alleged failure of their products, equipment or services." [10]

In addition to WHO staff, the only other observers that Repacholi invited to the WHO Task Group meeting in Geneva on 3 October to recommend exposure limits, were eight representatives from the power industry. Members of the press were barred from attending.[11] In addition the meeting was not publicised on either the WHO web site meetings list or the Bioelectromagnetics Society Newsletter's conference calendar and very few members of the EMF scientific community, including important EMF epidemiologists, were even aware of the meeting.[12] Only industry representatives received invitations. Why were the epidemiologists who were directly involved in the research that the WHO's risk assessment task group would evaluate, not also invited as observers and reviewers?

The *Microwave News* article points out that a number of independent researchers were involved in the preparation and review of the draft, but it was "highly unusual, if not unprecedented, for a WHO health document to be reviewed by so many with such strong ties to the affected industry,"[13]

One example of an industry reviewer's viewpoint, seeking to downplay potential health hazards, is seen in the comments from Michel Plante, representing Hydro-Quebec:

"The whole section on cancer seems more like a desperate attempt to maintain some positive statistical association from epidemiological studies alive than a factual and honest presentation of arguments both for and against carcinogenicity."[14]

Plante's role as a protector of his employer's interests in denying a cancer link with EMFs was amply demonstrated in his involvement, as a Hydro-Quebec representative, in suppressing potentially damaging cancer data in a 1994 Hydro-Quebec funded epidemiological study by Dr Gilles Theriault et al. from McGill University. The initial analysis of the data collected from three electric utilities found that workers who had the greatest exposures to magnetic fields had twelve times the expected rate of astrocytomas, a type of brain tumour, based on a small number of cases.[15]

In a later re-analysis of the data[16], this time looking at high frequency transients (HFT), the McGill University team found up to a 10-fold increased risk of developing lung cancer amongst highly exposed utility workers, with a "very clear" exposure-response relationship.[17]

When Gilles Theriault's McGill team wanted to further analyse the HFT data for other associations, Hydro-Quebec, which funded the $3 million study, and therefore owned the collected data, refused further access to the data. Plante said at the time that *"we have a contract problem that has to be resolved and there will be no new mandate until it is solved"*. Plante argued that by Theriault publishing the findings on HFT he had violated the contract with the utilities. Many senior EMF researchers and epidemiologists saw the HFT data as having important implications and needing further analysis by other researchers.[18] As of October 2005 the Hydro-Quebec HFT data has continued to be suppressed from any further analysis by the scientific community – and Plante, as Hydro-Quebec's man at the centre of that suppression, has now been asked by Repacholi to review the WHO's Environmental Health Criteria risk assessment.

It is not known if Plante was asked at the meetings about the "positive statistical association" seen in the Hydro-Quebec HFT data, but he could have replied that it is not important because it has not yet been replicated!

The Utility Health Sciences Group, another power industry group that Repacholi asked to review the EHC draft document, plainly indicated that they considered increased costs to industry should take precedence over health considerations when they proposed a change in the chapter on protective measures that stated:

"It should also be pointed out that redirecting facilities or redesigning electrical systems may be so expensive as to be inconsistent with the low-cost and no-cost steps typically viewed as prudent avoidance." [19]

The UHSG also proposed a statement be included in the summary:

"It would be useful for the summary to include a clear statement that the scientific research does not establish ELF EMF as a cause or contributing factor in any disease or adverse health effect, including cancer." [20]

The Myth of not accepting funding from industry

It is stated on the ICNIRP web site that in order to protect its status as an independent advisory body, " *ICNIRP also does not accept funding from industry*".[21] When it comes to the WHO's International EMF Project, however, no such restrictions apply. As Repacholi has stated, the:

"[EMF]*Project can receive funding from any source through Royal Adelaide Hospital; an agency established through WHO Legal Department agreement to collect funds for the project.*"[22]

Questions of a conflict-of-interest and even money laundering could be raised at this point when it was revealed by *Microwave News* that Repacholi, as head of the EMF Project, receives $150,000 annually from the cellphone industry.[23] However, Repacholi could rightfully still claim that he does not receive any direct funding from industry sources since it is funneled through the Royal Adelaide Hospital. This arrangement may be in violation of a current WHO rule against employees and consultants accepting any *"gift or remuneration"* from external sources *"incompatible"* with their duties to WHO.[24]

A Claytons oversight committee?

According to a fact sheet, *New Electromagnetic Fields Exposure Guidelines*, published by the European Commission in December 2005, an "International Advisory Committee" (IAC) has been set up to provide oversight to the WHO's International EMF Project. This committee consists of representatives of international organisations, independent scientific institutions and national governments who are supporting the Project.[25] In this case IAC oversight should essentially operate much the same as a judicial oversight committee where a judicial branch of the government watches or monitors what is going on or happening in a case or matter. In the judicial arena it is a form of checks and balances that operates to keep law officers from abusing their powers.[26] In the case of the WHO's EMF Project IAC oversight should operate to prevent WHO officials from abusing their powers - and this should include preventing the possibility of bias through conflict-of-interest. It would also be important for the IAC to maintain an arms-length distance from the project activities that it is supposed to monitor.

The question then needs to be asked of the IAC: Why have they failed to intervene in the case of blatant industry influence on the WHO's EMF Task Group?

Forgotten Lessons: Big Tobacco and Protecting the Integrity of WHO Decision Making

In July 2000 the WHO Committee of Experts on Tobacco Industry Documents released a 260-page report documenting the tactics used by the tobacco industry's strategies to undermine the work of the WHO.[27] At the same time the WHO issued a 15-page response document listing a detailed response to ensure that the WHO was never undermined again. Just a few of the 58 are worth quoting:

6. *WHO should urge other UN organisations to investigate possible tobacco company influences on their decisions and programs, and to report their findings publically.*
7. *WHO should advocate implementation and consistent enforcement of effective conflict of interest and ethics policies throughout UN agencies.*
8. *WHO should urge Member States to conduct their own investigations of possible tobacco company influence on national decisions and policies, and to publish reports on their findings.*
11. *Appoint an ombudsman or other independent offices, outside the standard lines of reporting authority, with autonomy and clear authority for enforcing ethical rules.*
12. *Disseminate conflict of interest rules more broadly.*
14. *Introduce a formal process for vetting prospective employees, consultants, advisers, and committee members, to identify conflicts of interest..*
19. *Prohibit employees, consultants, advisers, and committee members from holding any substantial financial affiliation with the tobacco industry, including any employee or consulting relationship. . .*

Such a blatant disregard for the fundamental principles of credible science as well as WHO's mission on protecting world health speaks of a desperation to bury independent science at all costs, even if that cost is the integrity of WHO.

20. *Disqualify any professional services from performing work on behalf of WHO if the firm also provides a tobacco company with services likely to be adverse to the interest of public health. . .*
21. *Prohibit employees, consultants, advisers and committee members from accepting any item of value from a Tobacco company or its affiliates. . .*
35. *WHO and IARC should take steps to educate their scientific investigators and collaborators about tobacco company efforts to undermine research and the need for special vigilance in protecting the integrity of tobacco-related research.*[28]

Although the above sample of WHO recommendations were in response to Big Tobacco's attempts to undermine WHO integrity, its direct relevance to other large industrial interests cannot be ignored, be it the power industry or telecommunications.

Unfortunately it seems that in this case at least, WHO has forgotten the hard lessons learnt with its previous experiences with Big Tobacco. In the case of WHO's Task Group writing the new Environmental Health Criteria (EHC) for power frequency EMFs, a violation of the above recommendations urgently calls for an independent evaluation to protect both public health and WHO's integrity.

In Conclusion

It is acknowledged that in an ever increasingly globalized world the reliance on international organisations to set standards to protect public health is an irrefutable fact of modern life. It is also a fact that international organizations charged with this task need to be "eternally vigilant" to ensure that their organisations are not co-opted by vested interests groups – as exampled by Big Tobacco and WHO.

However when it comes to non-ionizing radiation issues (in this case for power frequency health risk assessment) the evidence is clear that Michael Repacholi has used his standing in both WHO and ICNIRP to stack the WHO's Environmental Health Criteria Task Group for power frequency exposures with representatives of the power industry in contravention of WHO policy. This can only be to the detriment of the group's ability to evaluate the scientific literature in an unbiased way. This action can only be construed as being aimed at ensuring that industry involvement in determining the WHO Environmental Health Criteria will bias ICNIRP's risk assessment for power frequency exposure limits for years to come. This will conveniently provide economic protection for the industry against the need to spend enormous sums of money on upgrading distribution systems as well as risks of litigation. Such a blatant disregard for the fundamental principles of credible science, as well as WHO's mission on protecting world health, speaks of a desperation to bury independent science at all costs, even if that cost is the integrity of WHO.

The Author is not affiliated with any company supplying telecommunications services.

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ECC Statement No. 3
Witness: Richard J. Hoch
4/1/08 Pgh PX A-110172

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

In re: Application of Trans-Allegheny Interstate Line Company	:	Docket Nos. A-110172, A_110172F0002-F0004 and G-00071229

DIRECT TESTIMONY OF
RICHARD J. HOCH

October 31, 2007

Q. STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Richard J. Hoch and my permanent residence and business address is 1099 University Drive, Dunbar, Pennsylvania 15431.

EMPLOYMENT

Q. WHO ARE YOU EMPLOYED BY?

A. I am an Assistant Professor of Geography and Regional Planning at Indiana University of Pennsylvania. A copy of my curriculum vitae is attached as Exhibit RJH-1.

EDUCATION AND EXPERIENCE

Q. DESCRIBE YOUR EDUCATIONAL EXPERIENCE.

A. In 2005, I earned a Ph.D. in Geography, specializing in Planning and Regional Development from West Virginia University. In 1999, I earned a Master degree in Geography specializing in Geographic Information Systems [GIS] and Remote Sensing [RS]) from West Virginia University.

Q. DESCRIBE YOUR PROFESSIONAL EXPERIENCE.

A. I have spent more than 10 years studying the application of Geospatial data and methods (*i.e.*, GIS and RS) to the planning process. I have been employed as a land-use planner, GIS Specialist, Geospatial Coordinator, Geospatial Manager, and Remote Sensing Program Manager, where I have worked on several projects throughout Southwestern Pennsylvania, West Virginia, and the Mid-Atlantic Highlands.

I am a member of the Pennsylvania Planning Association (PPA), a member of PPA's parent association, the American Planning Association (APA), and a member of APA's professional and accredited arm, the American Institute of Certified Planners (AICP – AICP # 020887). I am also a member of the Association of State Flood Plane Manages I have earned the accreditation of a Certified Flood Plane Manager (CFM – CFM #761054).

PURPOSE OF TESTIMONY

Q. DESCRIBE THE PURPOSE OF YOUR TESTIMONY.

A. As a member of the American Institute of Certified Planners, I am required to serve the Public Interest, and as a Professor of Geography and Planning, I strive to encourage proper planning techniques, especially when applying Geographic Information Systems to the planning process. Therefore, I have been asked by the Energy Conservation Council of Pennsylvania to comment on the documentation pertaining to potential environmental impacts that has been prepared and presented by Trans-Allegheny Interstate Line Company ("TrAILCo") in presenting the Route Evaluation Report and Environmental Report for the TrAIL 500 kV Project Pennsylvania Portion (TrAILCo Exhibit JH-1) (referred to here as the "Report").

My testimony focuses on two components: 1.) the use of Geographic Information Systems (GIS) in preparing the site analysis, and 2.) my conclusions regarding the lack of actual impact analysis and documentation of the following: construction impacts, maintenance impacts, cumulative impacts, and secondary impacts.

Regarding the use of GIS in the Report, first, I comment on the general limitations of using GIS and its associated data sets as the primary method for environmental assessment and calculation. Second, I discuss the inappropriate use of particular data sets for the analysis performed, and point out where the appropriate documentation of the limitations of each data set was *not* noted in the report. Third, I identify environmental and topical components that, in my opinion, are non-existent, or 'missing' from this report.

Ultimately, it is my opinion that the PUC should require TrAILCo to, at minimum, mirror the compliance regulations as outlined in the National Environmental Policy Act's (NEPA) Environmental Impact Statement (EIS), regardless as to whether an official EIS is required under NEPA regulations or not. The EIS model, as enacted by NEPA in 1969 by the U.S. Congress, has served this country and the Public Interest for 38 years. The Public Interest should not be *replaced* by the National Interest; but that the National Interest should be *identified as* the Public Interest.

GIS

Q. WHAT IS GIS?

A. GIS is a system of software, hardware, datasets, and users that organizes stores, manipulates, analyzes, and displays particular types of environmental information. GIS is merely a tool to *assist* in the decision-making process. It is a generally accepted maxim in Geographic Information Science that GIS should never be the sole modeling approach or tool.

Q. WHY SHOULD GIS NEVER BE THE SOLE TOOL?

A. The leading reason why GIS should never be the sole tool relates to is the variation that exists among different data sets and GIS's potential for making precise calculations with datasets that are not intended to produce precise information. Metadata documents (defined as information about the information being used) accompany all publicly available datasets, and when these datasets are used in public documents or for analysis, said accompanying metadata should always be included with documents in order for the reader to understand the origin of the data, the purpose of the data, and the limitation of the data.

Q. WHY IS GIS A LIMITED A LIMITED TOOL FOR THIS REPORT?

A. The majority of the analysis performed in the Report used publicly available GIS and spatial data sets that are publicly available. Indeed, the Report states:

> Extensive use was made in the study of information from existing Geographic Information System ("GIS") data. This information was obtained from many sources, including Federal, State, and county governments. Much of this information was obtained through official agency GIS data access websites, some was provided directly Line Route Evaluation and Environmental Report TrAIL Project by government agencies, and some was created by the Routing Team by either digitizing information from paper-based maps or through aerial photo interpretation.

This report does not include any metadata about the GIS datasets used for analysis.

Q. DOES TRAILCO IN THE REPORT ACKNOWLEDGE THE LIMITATIONS OF GIS DATA?

A. The Routing Team does allude to the limitations of GIS data for comprehensive analysis,

> *The use of GIS data allows for the consideration and efficient use of a wide variety of information that would otherwise be unavailable or impractical to consider for a planning effort of this scope and schedule. GIS information is a highly effective tool when utilized for broad level planning studies, identifying and characterizing landscape level constraints and features, and developing environmental inventory information useful for comparisons between planning alternatives.*

Page 18 - Section 2.6 Environmental Data Collection.

The Routing Team goes further, stating the following;

> However, GIS data sources vary widely with respect to their accuracy and precision, and presentation, analysis, and calculations derived from these data sources requires careful consideration when used for planning purposes. For this reason, GIS based calculations and maps presented throughout this study should be considered to be reasonable approximations of the resource or geographic feature they represent, and not absolute measures or counts. They are presented in this study to allow for general comparisons between alternatives with the assumption that any inherent error or inaccuracies would be generally equal across all alternatives. (Emphasis added)

Id.

The Routing Team did take the proper measures in explaining the problematic use of GIS for detailed environmental reporting in Section 2.6 and in Table 2.2.

DATA USED IN THE REPORT

Q. DOES THE REPORT ADEQUATELY DISCUSS OR DISCLOSE THE LIMITATIONS IN THE DATASETS USED?

A. The Report does not fully disclose the known limitations of the datasets, the intended purpose of the datasets, or the inherent amount of known error in the datasets. This information is detailed explicitly in metadata.

Q. PLEASE EXPLAIN.

A. The report fails to reference the metadata directly nor does it provide the metadata documents. My testimony will review the intended purpose and stated use as documented in the metadata of three datasets that were used for the calculations in the report. They are:

- The National Hydrography Dataset (NHD)
- The National Wetlands Inventory (NWI)
- The National Land Cover Dataset (NLCD)

These datasets were identified in Table 2.2 of the report as the datasets used in the environmental analysis.

Q. WHAT IS THE NATIONAL HYDROGRAPHY DATASET?

A. The National Hydrography Dataset (NHD) is produced and published by the U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency. The NHD is produced at a 1:100,000 scale.

Q. EXPLAIN THE LIMITATIONS OF THE NATIONAL HYDROGRAHPY DATABASE?

A. This is a very coarse, nationwide scale that will not produce precise information that is necessary and is reported for this type of report. The primary data set used in producing the NHD was USGS topographic maps, which are produced at a 1:24,000 scale, therefore the original data was 're-scaled' from 1:24,000 to 1:100,000. A 1:24,000 scale map means that 1 inch on the map represents exactly 2,000 feet. A 100,000 scale map means that 1 inch on the map (or in the dataset) equals 1.6 miles.

The Completeness Report from the NHD Metadata (Exhibit RJH-2) states:

> The completeness of the data reflects the content of the sources, which, in the initial release of the National Hydrography Dataset, most often are U.S. Geological Survey topographic maps. Features found on the ground may have been eliminated or generalized on the source graphic because of scale and legibility constraints. In general, streams longer than one mile (approximately 1.6 kilometers) were collected. Most streams that flow from a lake were collected regardless of their length. Only definite channels were collected so not all swamp/marsh features have stream/rivers delineated through them. Lake/ponds having an area greater than 6 acres (approximately 2.4 hectares) were collected. Note, however, that these general rules were applied unevenly among maps during compilation. (Emphasis added).

Therefore, the documented limitations of this dataset are that it may or may not contain streams that are less than one mile in length and that is does not contain any lakes or ponds that are less than six acres in size. The NHD is not an appropriate data set to make precise calculations for a project of this scale.

Q. WHAT IS THE NATIONAL WETLANDS INVENTORY?

A. The National Wetlands Inventory (NWI) was used extensively in the report to identify the following categories of Natural Resources as identified in Table 2.2:

- Freshwater Pond
- Freshwater Emergent Wetlands
- Freshwater Forested
- Freshwater Forested/Shrub Wetland
- Lake

The NWI is produced and published by the U.S. Fish and Wildlife Service. The original source data for the production of the NWI come from a variety of aerial photos produced by various federal agencies that span four decades. The NWI dataset for the TrAILCo corridor in southwestern PA is derived from the National Aerial Photography Program that was acquired in the 1970s (see Diagram 1 in Appendices for NWI data vintages in USFWS Region 5).

Q. EXPLAIN THE LIMITATIONS OF THE NATIONAL WETLANDS INVENTORY?

A. The scale and accuracy of the NWI is extremely volatile. The Abstract from the NWI metadata (Exhibit RJH-3) states:

> The NWI maps do not show all wetlands since the maps are derived from aerial photo interpretation with varying limitations due to scale, photo quality, inventory techniques, and other factors. Consequently, the maps tend to show wetlands that are readily photo interpreted given consideration of photo and map scale. In general, the older NWI maps prepared from 1970s-era black and white photography (1:80,000 scale) tend to be very conservative, with many forested and drier-end emergent wetlands (e.g., wet meadows) not mapped. Maps derived from color infrared photography tend to yield more accurate results except when this photography was captured during a dry year, making wetland identification equally difficult. Proper use of NWI maps therefore requires knowledge of the inherent limitations of this mapping. It is suggested that users also consult other information to aid in wetland detection, such as U.S. Department of Agriculture soil survey reports and other wetland maps that may have been produced by state and local governments, and not rely solely on NWI maps. (Emphasis added)

The Purpose section of the NWI Metadata further explains;

> The purpose of this survey was not to map all wetlands and deepwater habitats of the United States, but rather to use aerial photo interpretation techniques to produce thematic maps that show, in most cases, the larger ones and types that can be identified by such techniques. The objective was to provide better geospatial information on wetlands than found on the U.S. Geological Survey topographic maps. It was not the intent of the NWI to produce maps that show exact wetland boundaries comparable to boundaries derived from ground surveys. Boundaries are therefore generalized in most cases. (Emphasis added)

The Completeness Report of the NWI Metadata explains the size of wetlands that are and are not identified;

> NWI maps do not show all wetlands, but attempt to show most photo interpretable wetlands given considerations of map/photo scale and wetland delineation practices. A target mapping unit (tmu) is an estimate of the size class of the smallest group of wetlands that NWI attempts to map consistently; it is not the smallest wetland mapped. Recognize that some wetland types are conspicuous and readily mapped (e.g., marshes and ponds) and smaller ones may be mapped. Drier wetlands and forested wetlands (especially evergreen) are more difficult to photo interpret and larger ones may be missed. The tmu also varies with photo scale; in forested regions, the tmu may be 3-5 acres (1:80K photos), 1-3 acres (1:58K), or 1 acre (1:40K). NWI maps should show most wetlands larger than the tmu. In the treeless prairies, a 1/4 acre tmu is possible due to the openness of terrain and occurrence of wetlands in distinct depressions. Take notice of the photo scale/type used to make the maps (see legend) and realize that black and white

> photos tend to yield more conservative interpretations than color infrared film. Most farmed wetlands (e.g., mucklands) are usually not mapped, except for pothole-type wetlands, cranberry bogs, and diked former tidelands (Sacramento Valley). Partly drained wetlands are conservatively mapped due to photo interpretation limitations. No attempt was made to identify regulated wetlands from other wetlands. Recognize that maps produced through photo interpretation are not as accurate as one prepared from on-the-ground surveys, so NWI boundaries are generalized. (Emphasis added).

Since the project area uses 1970 era photography (1:80,000 scale) as its source data, the Completeness Report states that the NWI identification of wetlands in forested areas within the project area is most likely limited to identifying forested wetlands 3-5 acres or greater. The identification of smaller wetlands is not likely with the NWI dataset.

Q. WHAT IS THE NATIONAL LAND COVER DATASET?

A. The National Land Cover Dataset (NLCD) is published cooperatively between the U.S. Geologic Survey (USGS) and the U.S. Environmental Protection Agency (USEPA). The NLCD is produced from LANDSAT Thematic Mapper (TM) satellite imagery.

Q. WHAT ARE THE LIMITATIONS OF THE NATIONAL LAND COVER DATASET?

A. The spatial resolution of this imagery is 30 meters. This means that the size of the smallest unit of measurement is 30 meters by 30 meters square.

Due to the coarseness of this data, the metadata (Exhibit RJH-4) clearly states:

Important Caution Advisory

With this in mind, users are cautioned to carefully scrutinize the data to see if they are of sufficient reliability before attempting to use the dataset for larger-scale or local analyses. (Emphasis added)

A spatial resolution of 30m means that all land cover within the bounds of a 30 meter by 30 meter square is generalized and interpolated to an average land cover within

that boundary. Therefore, no land covers that are smaller than 30m can be precisely identified without some margin of error. Field surveys should always be conducted and documented within a report when verifying land cover identified using the NLCD.

Also, the vintage of this data is from the early 1990s. This dataset is not temporally accurate or appropriate for conducting detailed analysis. Up to date and detailed land cover data is available from the Southwestern Pennsylvania Commission, but it appears that the SPC was not solicited for its extensive spatial data coverage of the project area.

ENVIRONMENTAL COMPONENTS MISSING FROM THE REPORT

Q. ARE THERE OTHER DEFICIENCIES WITH THE ENVIRONMENTAL COMPONENTS OF THE REPORT?

A. Yes. Most importantly is the reports lack of true *impact* analysis. This summary inventory provided in this report merely provides a list of environmental phenomenon. Nowhere in the report is there an explanation of this project's:

- Construction Impacts
- Maintenance Impacts
- Cumulative Impacts or
- Secondary Impacts.

Each of these four impacts pertaining to every environmental topic must be identified, studied, and considered before this process moves further.

Q. PLEASE PROVIDE SPECIFIC EXAMPLES OF ENVIRONMENTAL CONSIDERATIONS THAT ARE MISSING FROM THE REPORT?

A. An extensive analysis of the road network associated with the construction of this power line should be documented, as it is likely that many more miles of access road will be needed than the actual mileage of power line. Analysis of new roads should be performed for the general environmental and siting study, and the construction, maintenance, cumulative and secondary impacts as well.

Second, Groundwater is not mentioned in the report. The potential impacts to groundwater are significant in all phases, including construction, maintenance, cumulative

and secondary impacts. GIS data pertaining to point locations of registered wells and springs is freely available from the Pennsylvania Topographic and Geologic Survey. This data is updated periodically and is available via the internet at the following URL address: http://www.dcnr.state.pa.us/topogeo/groundwater/PaGWIS/PaGWISDownload.asp?Page=&UserType=

Third, Agricultural Security Areas (ASA) are not mentioned in the Report. ASAs are available for both Washington and Greene Counties from the Southwestern Pennsylvania Commission (See Exhibit RJH-5).

Fourth, the extent of underground mining is not addressed in the Report. GIS data delineating the existing and permitted extent of known deep mining in both Washington and Greene Counties is available upon request from the PA Department of Protection (PADEP).

Fifth, potential impacts to recreation trails are not sufficiently analyzed. Table 2.2 of the report indicates that a dataset produced for West Virginia was used to identify recreation trails in the study area, and that no other data sources were identified for trails in the study area. The SPC maintains a GIS dataset of the Bicycle/Pedestrian Network for the entire Southwest Pennsylvania region, including Washington and Greene Counties (See Exhibit RJH-5).

Finally, a complete and thorough socio-economic profile of the communities affected by the project is warranted. Information of each affected community should include, at minimum;

- Income data
- Poverty data
- Educational Attainment data

Such a profile ensures that social justice and environmental justice concerns are adequately addressed in the analysis.

Q. IN LIGHT OF YOUR TESTIMONY, WHAT ARE YOUR CONCLUSIONS?

A. My testimony has outlined why further environmental documentation is needed before any further action should be granted or permitted to the TrAILCo project. I have highlighted why GIS alone is not an appropriate tool for determining precise environmental impacts, but should be used as a precursor to more extensive and detailed on-the-ground field work surveys. I have a shown where particular datasets were used in an inappropriate matter for the desired and reported results and I have highlighted the absence of publicly available data sets in the analysis of the report. Finally, I have listed a non-extensive list of additional topics that warrant serious consideration and that were not mentioned in this report. Due to the inadequate and incomplete nature of the environmental impacts of this report's design, the Commission should require TrAILCo to perform a NEPA EIS, or a NEPA-style EIS report, in order to properly serve the Public Interest and in the interest of proper environmental stewardship. I thank you for your time and your serious contemplation in this matter.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

Curriculum Vitae

Richard J. Hoch, Ph.D., AICP

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Education

8/99 - 12/05	Ph.D. Geography *(Planning and Regional Development)*, West Virginia University (WVU).
8/97 - 6/99	M.A. Geography *(Geographic Information Systems & Remote Sensing)*, WVU.
8/91 - 12/92	B.A. History *(Environmental & Industrial)*, University of Pittsburgh.
8/88 - 5/91	Penn State University.

Professional Appointments and Employment

08/07 – present	Assistant Professor, Department of Geography and Regional Planning, Indiana University of Pennsylvania (IUP)
12/05 – present	Adjunct Assistant Professor, Department of Geology and Geography, WVU.
10/05 – 5/06	LiDAR – Remote Sensing Program Manager / Research Associate, Canaan Valley Institute.
3/05 – 10/05	Geospatial Manager, Canaan Valley Institute.
7/04 – 3/05	Geospatial Coordinator, Canaan Valley Institute.
12/03 – 6/04	Strategic Planner / GIS Analyst, Schwan's Food Company.
5/99 – 8/03	Land-use Planner / GIS Specialist, Skelly & Loy, Engineers and Consultants.
8/00 – 12/01	Graduate Instructor, Department of Geology and Geography, WVU.
8/98 - 4/00	Graduate Teaching Assistant, Department of Geology and Geography, WVU.

Certifications

- American Institute of Certified Planners (AICP - #020887).
- Certified Floodplain Manager (CFM - #761054), Association of State Floodplain Managers.

Teaching Profile

Courses Taught:

- Introduction to Planning
- Geography of the Non-Western World
- Climate and Environment
- Urban Geography
- World Regional Geography
- Remote Sensing of the Environment (lab)
- Geography of Latin America (Spring 2008)
- Introduction to GIS (Spring 2008)

Teaching Assistant:

- Introduction to Human Geography
- Rural and Regional Development
- Urban and Regional Planning
- Introduction to Remote Sensing
- Economic Geography
- Climate and Environment
- Geography of Europe

Research Specialties

- Applied GISc in the Planning Process
- Uneven Regional Development
- Urban Political Ecology
- Nature and the State

Publications

Hoch, R. J. and Hanham, R. Q. A Geospatial Analysis of Municipal Land-use Policy and Land-use Change in Metropolitan Pittsburgh. Submitted to *Applied Geography.*

Hoch R. J. Nature and the Local State: The Uneven Development of Ohiopyle State Park. In preparation to be submitted to *Urban Geography.*

External Funding Awards

Center for Rural Pennsylvania, *Analyzing the fiscal and spatial efficacy of small-business grant programs in rural Pennsylvania.* Grant award - $50,000 (pending approval). Collaborative project with Dr. Terry Halfhill, Eberly Distinguished Fellow of Business, Penn State University.

Commonwealth of Pennsylvania Growing Greener Program Grants:

2002 4 projects, total grant awards: $150,000
2001 2 projects, total grant awards: $87,000
2000 2 projects, total grant awards: $86,000

Conference Presentations

Hoch, R. J. 2006. *An Analysis of Fragmented Land-use Policy and Land-use Change: The Case Study of Metropolitan Pittsburgh.* Session titled: 'Planning and Urban Sprawl: Local and Regional Variations in the US sponsored by Regional Development and Planning group. Annual meeting of the Association of American Geographers, Chicago, IL.

Hoch, R. J. 2005. *LiDAR Acquisition and Application.* ASPRS sponsored session. The Pennsylvania Geographical Society, Greensburg, PA.

Hoch, R. J. 2005. Panelist in session titled: 'Making Your Own Way: Grant Proposal Writing for Graduate School and Beyond', sponsored by the Jobs in Geography Committee. Annual meeting of the Association of American Geographers, Denver, Colorado.

Hoch, R. J. 2004. *Assessing the Relationship between Local Land-use Policy and Land-use Change in Metropolitan Pittsburgh.* Annual meeting of the Association of American Geographers, Philadelphia, PA.

Hoch, R. J. 2000. *Uneven Development of Nature: An Historical Geography of Ohiopyle State Park.* Annual meeting of the Association of American Geographers, Pittsburgh, PA.

Hoch, R. J. 2000. Panelist in session titled: 'Developing Geographies, Graduate Research on Regional Development and Planning', sponsored by Regional Development and Planning Specialty Group. Annual meeting of the Association of American Geographers, Pittsburgh, PA.

Hoch, R. J. 1999. *Producing a Nature Landscape: A Case Study of Ohiopyle State Park.* Annual meeting of the Middle States Division of the American Association of Geographers, West Chester, PA.

Invited Presentations

2nd Annual Appalachian Remote Sensing Conference, 2005. Developed and coordinated presentation titled, *LiDAR Operations, Processing and Applications.*

West Virginia Department of Environmental Protection, 2003. Presentation titled, *Stormwater Management and Asset Assessment Utilizing Geographic Information Systems: Preparing for the EPA MS4, Phase II Requirement.*

Connellsville Area High School – Teacher in-service day, 2003. *New Methods in Teaching Ecology in the Classroom: A GIS Approach.*

Awards

Endowed Doctoral Teaching Fellowship. Eberly College of Arts and Sciences, 2001.

Endowed Doctoral Teaching Fellowship. Eberly College of Arts and Sciences, 2000.

Outstanding Graduate Teaching Assistant. Department of Geography, Eberly College of Arts and Sciences, 2000.

Outstanding Graduate Teaching Assistant. Department of Geography, Eberly College of Arts and Sciences, 1999.

Related Training

REALM Survey Suite and ALTM Digital Aerial Camera. Remote Sensing (LiDAR) Data Processing Training Program. Optech Incorporated. March 2005.

Natural Stream Channel Design / Applied Fluvial Geomorphology (Rosgen I). Wildland Hydrology Consultants. June 2005.

Presenting Data and Information, Edward Tufte. September 2004.

International Watershed Remote Sensing Workshop sponsored by the European Union and the US Department of Education; held in Xanthi, Greece. May 2001.

Graduate Committees Served

Thomas A. Page, M.S. (graduated). West Virginia University, Department of Forestry and Natural Resources (Fisheries). 2004 – 2006.

Michael Mandeville, M.A. West Virginia University, Department of Geology and Geography (Geography). 2006 – present.

Jacob Drvar. M.A. West Virginia University, Department of Geology and Geography (Geography). 2007 – present.

Denyese Wyskup. Ph.D. West Virginia University, Department of Geology and Geography (Geography). 2007 – present.

Other Service

Steering Committee / Plan Reviewer, Mountain Area Multi-Municipal Comprehensive Plan for the communities of Stewart Township (grantee), Wharton Township, Henry Clay Township, Springfield Township, Saltlick Township, Ohiopyle Borough, Markelysburg Borough. Fayette County, PA. Contracted by Mackin Engineering to analyze tourism economic impact. Pittsburgh, PA (ongoing).

Project Oversight Review, Greene County, PA Community GeoPortal. Contracted by Greene County Office of Economic Development (upcoming).

Technical Assistance Volunteer, Youghiogheny Riverkeeper (ongoing).

Board of Directors (Secretary), Mountain Watershed Association (2003 – 2004).
Contact: Beverly Braverman.

Graduate Representative, Search Committee for Geography Program GIS and Natural Resources faculty position (spring, 2002).

Volunteer, *The Institute for the History of Technology & Industrial Archaeology*. Serve on an as-needed volunteer basis for GIS and RS project needs (2000– 2001). Contact: Dan Bonenberger.

Graduate Representative, Geography Graduate Program Committee, WVU (8/98 – 5/02).

Graduate Representative. Graduate Student Council, WVU (8/98 – 5/00).

Co-Organizer of field trip (w/ Lizabeth Pyle) for national meeting of American Association of Geographers. Pittsburgh, April 5, 2000. Field trip title: *Recreational Retreats and Rural Landscapes in the Laurel Highlands.*

Volunteer, Ohiopyle State Park (1996 – 1998) Contact: Barbara Drbal Wallace.

Technical Documents

- *Morgan County, WV Comprehensive Plan* – Groundwater Risk-analysis. Analysis of groundwater resources vulnerability for County Comprehensive Plan (ongoing).

- *Tucker County, WV Comprehensive Plan* – Prepared 'alternative futures' scenarios for County Comprehensive Planning effort that provided economic impacts of various land-use development patterns based on existing conditions and proposed policy alternatives (ongoing).

- *Gilmer County, WV Enhanced Digital Flood Insurance Rate Mapping (E-DFIRM).* Project Manager of delineation of floodplain mapping based on public input, fluvial geomorphology, hydrology and advanced laser terrain topographic data provided by LiDAR technology (ongoing).

- *Raccoon Creek Watershed Abandoned Mine Drainage (AMD) Survey and Preliminary Restoration Plan, EPA Section 104(b)(3) Document.* Primary Investigator. Prepared for Raccoon Creek Watershed Association, Washington, PA.

- *Indian Creek Watershed River Conservation Plan (RCP).* Primary Investigator. In compliance with the Pennsylvania DCNR Watershed Management Registry. Prepared for the Mountain Watershed Assoc., Melcroft, PA.

- *Upper Chartiers Creek River Conservation Plan (RCP).* Primary Investigator. In compliance with the Pennsylvania DCNR Watershed Management Registry. Prepared for Chartiers Creek Nature Conservancy, Washington, PA.

- *Cross Creek Watershed Assessment, Protection and Restoration Plan.* Project Manager and Primary Investigator. Prepared for the Cross Creek Watershed Association, Avella, PA.

- *Garrett County, MD Landfill Mapping Project.* Project Manager and Primary Investigator. Prepared for Garrett County Solid Waste Authority.

- *Indian Creek Watershed Acid Mine Drainage and Abandoned Mine Land Mapping.* Project Manager and Primary Investigator. Prepared for the Mountain Watershed Assoc., Melcroft, PA.

- *Carbon Fuel Survey.* Primary Investigator. Study involved spatial analysis of abandoned coal refuse as a fuel resource for proposed power plant. Client confidential.

- *Mill Run Creek, PA Fluvial Geomorphology Survey and Assessment.* Surveyed stream health using Rosgen protocol and USDA Visual Assessment guidelines. Prepared for the Mountain Watershed Assoc., Melcroft, PA.

- *Upper Indian Creek Fluvial Geomorphology Assessment.* Surveyed stream health using Rosgen protocol and USDA Visual Assessment guidelines. Prepared for the Mountain Watershed Assoc., Melcroft, PA.

- *MTBE (methyl tertiary-butyl ether) Study of Northern West Virginia.* Prepared for the WV Dept. of Public Health.

- *Hinton, WV Area Fluvial Geomorphology Study for Highway Upgrades.* Prepared for WVDOH.

- *Environmental Assessment, United States Department of Energy, Pittsburgh PA and Morgantown WV.* Primary Investigator. Prepared for USDOE NETL.

- *Donohoe Creek Watershed Assessment, Hempfield Twp.*, Westmoreland County. Prepared for the Westmoreland County Conservation District.

Professional Organizations

- American Institute of Certified Planners
- American Planning Association / Pennsylvania Planning Association
- Association of American Geographers
- Association of State Floodplain Managers
- Pennsylvania Geographical Society
- Pennsylvania Mapping and Geographic Information Consortium (PAMAGIC)

ECC Exhibit RJH-2

Back to report

NHD Metadata

Originator:
U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency
Title:
National Hydrography Dataset
Publication Place:
Reston, Virginia
Publication Date:
1999
Publisher:
U.S. Geological Survey
Abstract:
The National Hydrography Dataset (NHD) is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that comprise the nations surface water drainage system. It is based initially on the content of the U.S. Geological Survey 1:100,000-scale Digital Line Graph (DLG) hydrography data, integrated with reach-related information from the U.S. Environmental Protection Agency Reach File Version 3.0 (RF3). More specifically, it contains reach codes for networked features and isolated lakes, flow direction, names, stream level, and centerline representations for areal water bodies. Reaches are also defined to represent waterbodies and the approximate shorelines of the Great Lakes, the Atlantic and Pacific Oceans, and the Gulf of Mexico. The NHD also incorporates the National Spatial Data Infrastructure framework criteria set out by the Federal Geographic Data Committee.
Purpose:
The National Hydrography Dataset combines elements of the DLG and RF3: spatial accuracy and comprehensiveness from the DLG and network relationships, names, stream level, and a unique identifier (reach code) for surface water features from RF3. The NHD supersedes DLG and RF3 by incorporating them, not by replacing them. Users of DLG and RF3 will find the National Hydrography Dataset both familiar and greatly expanded and refined. The NHD provides a national framework for assigning reach addresses to water-related entities, such as industrial dischargers, drinking water supplies, fish habitat areas, wild and scenic rivers. Reach addresses establish the locations of these entities relative to one another within the NHD surface water drainage network in a manner similar to street addresses. Once linked to the NHD by their reach addresses, the upstream/downstream relationships of these water-related entities and any associated information about them can be analyzed using software tools ranging from spreadsheets to geographic information systems (GIS). GIS can also be used to combine NHD-based network analysis with other data layers, such as soils, land use and population, to help better understand and display their respective effects upon one another. Furthermore, because the NHD provides a nationally consistent framework for addressing and analysis, water-related information linked to reach addresses by one organization (national, state, local) can be shared with other organizations and easily integrated into many different types of applications to the benefit of all. The National Hydrography Dataset is designed to provide comprehensive coverage of hydrologic data for the U.S. While initially based on 1:100,000-scale data, the NHD is designed to incorporate - and encourage the development of - higher-resolution data required by many users. It will facilitate the improved integration of water-related data in support of the application requirements of a growing national user community and will enable shared maintenance and enhancement.
Progress:
Complete
Maintenance and Update Frequency:
Irregular
Theme Keyword Thesaurus:
U.S. Department of the Interior, U.S. Geological Survey, 1997, Standards for National Hydrography Dataset(http://mapping.usgs.gov/standards/)

Theme Keyword:
Hydrography
Theme Keyword:
Stream / River
Theme Keyword:
Lake / Pond
Theme Keyword:
Canal / Ditch
Theme Keyword:
Reservoir
Theme Keyword:
Spring / Seep
Theme Keyword:
Swamp / Marsh
Theme Keyword:
Artificial Path
Theme Keyword:
Reach

Access Constraints:
None

Use Constraints:
None. Acknowledgment of the originating agencies would be appreciated in products derived from these data.

Attribute Accuracy Report:
The accuracy of the attributes of the Digital Line Graph data is estimated to be 98.5 percent. One or more of the following methods were used to test attribute accuracy: - manual comparison of the source with hardcopy plots. - symbolized display of the digital line graph on an interactive computer graphic system. - Selected attributes that could not be visually verified on plots or on screen were interactively queried and verified on screen. In addition, software validated feature types and characteristics against a master set of types and characteristics, checked that combinations of types and characteristics were valid, and that types and characteristics were valid for the delineation of the feature. Feature types, characteristics, and other attributes conform to the Standards for National Hydrography Dataset (USGS, 1999) as of the date they were loaded into the database. All names on reaches were validated against a March 1999 extract from the Geographic Names Information System. The entry and identifier for the names match those in the Geographic Names Information System. The association of each name to reaches has not been methodically checked, and so a name may be applied to the wrong reaches. Anecdotal reviews indicate that 80 percent or more of the named reaches have the correct name. Reaches were delineated with a batch procedure and were checked extensively during the visual pass steps of processing. Based on automated quality assurance/quality control checks performed at various intervals during the processing, approximately 99 percent of the reaches are delineated according to standards.

Logical Consistency Report:
Points, nodes, lines, and areas conform to topological rules. Lines intersect only at nodes, and all nodes anchor the ends of lines. Lines do not overshoot or undershoot other lines where they are supposed to meet. There are no duplicate lines. Lines bound areas and lines identify the areas to the left and right of the lines. Gaps and overlaps among areas do not exist. All areas close.

Completeness Report:
The completeness of the data reflects the content of the sources, which, in the initial release of the National Hydrography Dataset, most often are U.S. Geological Survey topographic maps. Features found on the ground may have been eliminated or generalized on the source graphic because of scale and legibility constraints. In general, streams longer than one mile (approximately 1.6 kilometers) were collected. Most streams that flow from a lake were collected regardless of their length. Only definite channels were collected so not all swamp/marsh features have stream/rivers delineated through them. Lake/ponds having an area greater than 6 acres (approximately 2.4 hectares) were collected. Note, however, that these general rules were applied unevenly among maps during compilation. Some map quadrangles have a much sparser pattern of hydrography than do adjoining maps and these differences continue in the digital rendition of these features. A priority for maintenance of the National Hydrography Dataset is the rectification of these differences. Transport

reaches are defined on nearly all features of type stream/river, canal/ditch, artificial path, pipeline, and connector. Waterbody reaches are defined on the subset of lake/pond features that were identified as waterbodies during the development of Reach File Version 3. Most attention in applying geographic names was given to transport reaches that follow stream/rivers and waterbody reaches. Near the international boundaries with Canada and Mexico, only the parts of features within the United States are delineated. Detailed capture conditions are provided for every feature type in the Standards for National Hydrography Dataset (USGS, 1999), available online through http://mapping.usgs.gov/standards/.

Horizontal Positional Accuracy Report:

Statements of horizontal positional accuracy are based on accuracy statements made for U.S.Geological Survey topographic quadrangle maps. These maps were compiled to meet National Map Accuracy Standards. For horizontal accuracy, this standard is met if at least 90 percent of points tested are within 0.02 inch (at map scale) of their true position. Additional offsets to positions may have been introduced where there are many features to improve the legibility of map symbols. In addition, the digitizing of maps is estimated to contain a horizontal positional error of less than or equal to 0.003 inch standard error (at map scale) in the two component directions relative to the source maps. Visual comparison between the map graphic (including digital scans of the graphic), and plots or digital displays of points, lines, and areas, is used to assess the positional accuracy of digital data. Linear features of the same type along the adjoining edges of data sets are aligned if they are within a 0.02 inch tolerance (at map scale). To align the features, the midpoint between the end of the corresponding features is computed, and the ends of features are moved to this point. Features outside the tolerance are not moved; instead, a feature of type connector was added to join the features.

Vertical Positional Accuracy Report:

Statements of vertical positional accuracy for elevation of water surfaces are based on accuracy statements made for U.S. Geological Survey topographic quadrangle maps. These maps were compiled to meet National Map Accuracy Standards. For vertical accuracy, this standard is met if at least 90 percent of well-defined points tested are within one-half contour interval of the correct value. Elevations of water surface printed on the published map meet this standard; the contour intervals of the maps vary. These elevations were transcribed into the digital data; the accuracy of this transcription was checked by visual comparison between the data and the map.

Direct Spatial Reference Method:

Vector

Latitude Resolution:

0.0000001

Longitude Resolution:

0.0000001

Geographic Coordinate Units:

Decimal Degrees

Horizontal Datum Name:

North American Datum of 1983

Ellipsoid Name:

Geodetic Reference System 80

Semi-major Axis:

6378137.0000000

Denominator of Flattening Ratio:

298.2570000

Altitude Datum Name:

National Geodetic Vertical Datum of 1929

Altitude Resolution (Primary):

0.1000000

Altitude Distance Units:

Meters

Altitude Encoding Method:

Attribute Values

Entity and Attribute Overview:

The National Hydrography Dataset is a comprehensive set of digital spatial data that encodes information about naturally occurring and constructed bodies of water, paths through which water flows, and related entities. The information encoded about features includes classification by type, other characteristics, a unique common identifier, the feature length or area, and (rarely) the

elevation of the surface of water pools and a description of the stage of the elevation. For reaches, encoded information includes a reach code, the date the reach code was assigned, a unique common identifier, the reach length or area, and, for transport reaches, the stream level. Geographic names, and their identifiers in the Geographic Names Information System, are assigned to reaches or, if no reach is available, to features. The data also contain relations among reaches that encode the direction of water flow, metadata, and information that supports the exchange of future updates and improvements to the data.

Entity and Attribute Detail Citation:

The names and definitions of all feature types, characteristics, and values are in U.S. Geological Survey, 1999, Standards for National Hydrography Dataset: Reston, Virginia, U.S.Geological Survey. The document is available online through http://mapping.usgs.gov/standards/. Information about tables and fields in the data are available from the user documentation for the National Hydrography Dataset.

Metadata Date:

1998

Metadata Standard Name:

FGDC Content Standards for Digital Geospatial Metadata

Metadata Standard Version:

19940608

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National Wetlands Inventory (NWI) Metadata

NOTE: This metadata document represents the static text elements of the National Wetlands Inventory (NWI) Metadata. Quad-specific metadata files are available through the FGDC Clearinghouse website.

Metadata:

Identification_Information:

Citation:

Citation_Information:

Originator: U.S. Fish & Wildlife Service, National Wetlands Inventory

Publication_Date: Ranges from Oct. 1981 to present; information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Title: National Wetlands Inventory -- Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Publication_Information:

Publication_Place: St.Petersburg, Florida

Publisher: U.S. Fish & Wildlife Service, National Wetlands Inventory

Online_Linkage:
ftp://ftp.nwi.fws.gov/arcdata/
ftp://ftp.nwi.fws.gov/shapedata/

Description:

Abstract:
NWI digital data files are records of wetlands location and classification as developed by the U.S. Fish & Wildlife Service. The classification system was adopted as a national classification standard in 1996 by the Federal Geographic Data Committee. This dataset is one of a series available in 7.5 minute by 7.5 minute blocks containing ground planimetric coordinates of wetlands point, line, and polygon features and wetlands attributes. When completed, the series will provide coverage for all of the contiguous United States, Hawaii, Alaska, and U.S. protectorates in the Pacific and Caribbean. Coverage includes both digital data and hardcopy maps. The NWI maps do not show all wetlands since the maps are derived from aerial photointerpretation with varying limitations due to scale, photo quality, inventory techniques, and other factors. Consequently, the maps tend to show wetlands that are readily photointerpreted given consideration of photo and map scale. In general, the older NWI maps prepared from 1970s-era black and white photography (1:80,000 scale) tend to be very conservative, with many forested and drier-end emergent wetlands (e.g., wet meadows) not mapped. Maps derived from color infrared photography tend to yield more accurate results except when this photography was captured during a dry year, making wetland identification equally difficult. Proper use of NWI maps therefore requires knowledge of the inherent limitations of this mapping. It is suggested that users also consult other information to aid in wetland detection, such as U.S. Department

of Agriculture soil survey reports and other wetland maps that may have been produced by state and local governments, and not rely solely on NWI maps. See section on "Completeness_Report" for more information. Also see an article in the National Wetlands Newsletter (March-April 1997; Vol. 19/2, pp. 5-12) entitled "NWI Maps: What They Tell Us" (a free copy of this article can be ordered from U.S. Fish and Wildlife Service, ES-NWI, 300 Westgate Center Drive, Hadley, MA 01035, telephone, 413-253-8620).

Purpose:
The data provide consultants, planners, and resource managers with information on wetland location and type. The data were collected to meet U.S. Fish & Wildlife Service's mandate to map the wetland and deepwater habitats of the United States. The purpose of this survey was not to map all wetlands and deepwater habitats of the United States, but rather to use aerial photointerpretation techniques to produce thematic maps that show, in most cases, the larger ones and types that can be identified by such techniques. The objective was to provide better geospatial information on wetlands than found on the U.S. Geological Survey topographic maps. It was not the intent of the NWI to produce maps that show exact wetland boundaries comparable to boundaries derived from ground surveys. Boundaries are therefore generalized in most cases. Consequently, the quality of the wetland data is variable mainly due to source photography, ease or difficulty of interpreting specific wetland types, and survey methods (e.g., level of field effort and state-of-the-art of wetland delineation). See section on "Completeness_Report" for more information.

Time_Period_of_Content:

Time_Period_Information:

Multiple_Dates_Times:

Calendar_Date: Ranges from Feb. 1971 to Nov. 1997.
Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Currentness_Reference: Source photography date

Status:

Progress: Complete

Maintenance_and_Update_Frequency: Irregular

Spatial_Domain:

Bounding_Coordinates:

West_Bounding_Coordinate: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

East_Bounding_Coordinate: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

North_Bounding_Coordinate: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

South_Bounding_Coordinate: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Keywords:

Theme:

Theme_Keyword_Thesaurus: None

Theme_Keyword: wetlands

Theme_Keyword: hydrologic

Theme_Keyword: land cover

Theme_Keyword: surface and manmade features

Place:

Place_Keyword_Thesaurus: USGS Quadrangle Names

Place_Keyword: Range includes all 50 states, Puerto Rico, Virgin Islands. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Access_Constraints: None

Use_Constraints:
Federal, State, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any Federal, State, or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate Federal, State, or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.

Point_of_Contact:

Contact_Information:

Contact_Organization_Primary:

Contact_Organization: U.S. Fish & Wildlife Service, National Wetlands Inventory Center

Contact_Position: Cartographer

Contact_Address:

Address_Type: Mailing and Physical address

Address: 9720 Executive Center Drive
City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33702
Country: US

Contact_Voice_Telephone: 727-570-5400

Data_Quality_Information:

Attribute_Accuracy:

Attribute_Accuracy_Report:
The attribute accuracy is tested by manual comparison of the source with hard copy printouts and/or symbolized display of the digital wetlands data on an interactive computer graphic

system. In addition, quality control verification software (USFWS-NWI) tests the attributes against a master set of valid wetland attributes.

Logical_Consistency_Report:
Polygons intersecting the neatline are closed along the border. Segments making up the outer and inner boundaries of a polygon tie end-to-end to completely enclose the area. Line segments are a set of sequentially numbered coordinate pairs. No duplicate features exist nor duplicate points in a data string. Intersecting lines are separated into individual line segments at the point of intersection. Point data are represented by two sets of coordinate pairs, each with the same coordinate values. All nodes are represented by a single coordinate pair which indicates the beginning or end of a line segment. The neatline is generated by connecting the four corners of the digital file, as established during initialization of the digital file. All data crossing the neatline are clipped to the neatline and data within a specified tolerance of the neatline are snapped to the neatline. Tests for logical consistency are performed by quality control verification software (USFWS-NWI).

Completeness_Report:
NWI maps do not show all wetlands, but attempt to show most photointerpretable wetlands given considerations of map/photo scale and wetland delineation practices. A target mapping unit (tmu) is an estimate of the size class of the smallest group of wetlands that NWI attempts to map consistently; it is not the smallest wetland mapped. Recognize that some wetland types are conspicuous and readily mapped (e.g., marshes and ponds) and smaller ones may be mapped. Drier wetlands and forested wetlands (especially evergreen) are more difficult to photointerpret and larger ones may be missed. The tmu also varies with photo scale; in forested regions, the tmu may be 3-5 acres (1:80K photos), 1-3 acres (1:58K), or 1 acre (1:40K). NWI maps should show most wetlands larger than the tmu. In the treeless prairies, a 1/4 acre tmu is possible due to the openness of terrain and occurrence of wetlands in distinct depressions. Take notice of the photo scale/type used to make the maps (see legend) and realize that black and white photos tend to yield more conservative interpretations than color infrared film. Most farmed wetlands (e.g., mucklands) are usually not mapped, except for pothole-type wetlands, cranberry bogs, and diked former tidelands (Sacramento Valley). Partly drained wetlands are conservatively mapped due to photointerpretation limitations. No attempt was made to identify regulated wetlands from other wetlands. Recognize that maps produced through photointerpretation are not as accurate as one prepared from on-the-ground surveys, so NWI boundaries are generalized.

Positional_Accuracy:

Horizontal_Positional_Accuracy:

Horizontal_Positional_Accuracy_Report: Horizontal

Lineage:

Source_Information:

Source_Citation:

Originator:
The Domain includes U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA), National

Aeronautics and Space Administration (NASA), special project. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Publication_Date: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Title:
The Domain includes National Aerial Photography Program (NAPP), National High Altitude Photography (NHAP), USDA, Farm Service Agency, Aerial Photography Field Office, NASA or special project photography. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Geospatial_Data_Presentation_Form: Remote-sensing image

Publication_Information:

Publication_Place: Reston, Virginia

Publisher: U.S. Geological Survey

Source_Scale_Denominator: Ranges from 20,000 to 132,000. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Type_of_Source_Media: Domain includes black and white, color infrared, or natural color aerial photograph film transparency. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Source_Time_Period_of_Content:

Time_Period_Information:

Multiple_Dates_Times:

Calendar_Date: Ranges from Feb. 1971 to Nov. 1997. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Source_Currentness_Reference: Photo date

Source_Citation_Abbreviation: PHOTOS

Source_Contribution: Wetlands spatial and attribute information

Source_Information:

Source_Citation:

Citation_Information:

Originator: U.S. Geological Survey

Publication_Date: Ranges from 1902 to 1995. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Title: topographic map

Geospati al_Data_Presentation_Form: map

Publication_Information:

```
            Publication_Place: Reston, Virginia

            Publisher: U.S. Geological Survey

        Source_Scale_Denominator: Domain includes 20000, 24000,
        25000, 30000, and 62500. Information for this element varies
        for each 7.5' quad. See the quad-specific metadata file.

        Type_of_Source_Media: stable-base material

        Source_Time_Period_of_Content:

          Time_Period_Information:

            Single_Date_Time:

              Calendar_Date: Ranges from 1902 to 1995.
              Information for this element varies for each 7.5'
              quad. See the quad-specific metadata file.

          Source_Currentness_Reference: publication date

        Source_Citation_Abbreviation: USGS QUAD

        Source_Contribution: base cartographic data

      Source_Information:

        Source_Citation:

          Citation_Information:

            Originator: U.S.D.A. Natural Resources Conservation
            Service

            Publication_Date: Varies

            Title: County Soil Surveys

            Geospatial_Data_Presentation_Form: map

            Publication_Information:

              Publication_Place: Washington, DC

              Publisher: Government Printing Office

        Source_Scale_Denominator: Varies

        Type_of_Source_Media: paper

        Source_Time_Period_of_Content:

          Time_Period_Information:

            Single_Date_Time:

              Calendar_Date: Varies

          Source_Currentness_Reference: publication date

        Source_Citation_Abbreviation: SOILS

        Source_Contribution: wetlands location and classification

      Process_Step:
```

Process_Description:
NWI maps are compiled through manual photointerpretation of NHAP or NAPP aerial photography supplemented by Soil Surveys and field checking of wetland photo signatures. Delineated wetland boundaries are manually transferred from interpreted photos to USGS 7.5 minute topographic quadrangle maps and then manually labeled. Quality control steps occur throughout the photointerpretation, map compilation, and map reproduction processes. Digital wetlands data are either manually digitized or scanned from stable-base copies of the 1:24,000 scale wetlands overlays registered to the standard U.S. Geological Survey (USGS) 7.5 minute quadrangles into topologically correct data files using Arc/Info software. Files contain ground planimetric coordinates and wetland attributes. The quadrangles were referenced to the North American Datum of 1927 (NAD27) horizontal datum. The scanning process captured the digital data at a scanning resolution of at least 0.001 inches; the resulting raster data were vectorized and then attributed on an interactive editing station. Manual digitizing used a digitizing table to capture the digital data at a resolution of at least 0.005 inches; attribution was performed as the data were digitized. The determination of scanning versus manual digitizing production method was based on feature density, source map quality, feature symbology, and availability of production systems. The data were checked for position by comparing plots of the digital data to the source material.

Source_Used_Citation_Abbreviation: PHOTOS

Source_Used_Citation_Abbreviation: USGS QUADS

Process_Date: Ranges from 1979 to 2001. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Source_Produced_Citation_Abbreviation: NWI

Spatial_Data_Organization_Information:

Direct_Spatial_Reference_Method: Vector

Point_and_Vector_Object_Information:

SDTS_Terms_Description:

SDTS_Point_and_Vector_Object_Type: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Spatial_Reference_Information:

Horizontal_Coordinate_System_Definition:

Planar:

Grid_Coordinate_System:

Grid_Coordinate_System_Name: Universal Transverse Mercator

Universal_Transverse_Mercator:

UTM_Zone_Number: Ranges from 4 to 20. Information for this element varies for each 7.5' quad. See the

quad-specific metadata file.

Transverse_Mercator:

Scale_Factor_at_Central_Meridian: 0.9996

Longitude_of_Central_Meridian: Ranges from -159.0 to -63.0. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Latitude_of_Projection_Origin: 0.0

False_Easting: 500000.0

False_Northing: 0.0

Planar_Coordinate_Information:

Planar_Coordinate_Encoding_Method: Coordinate pair

Coordinate_Representation:

Abscissa_Resolution: 0.61

Ordinate_Resolution: 0.61

Planar_Distance_Units: Meters

Geodetic_Model:

Horizonal_Datum_Name: North American Datum of 1927

Ellipsoid_Name: Clarke 1866

Semi_major_Axis: 6378206.4

Denominator_of_Flattening_Ratio: 294.9787

Entity_and_Attribute_Information:

Detailed_Description:

Entity_Type:

Entity_Type_Label: Wetland

Entity_Type_Definition: Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following attributes: 1) at least periodically, the land supports predominantly hydrophytes; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Entity_Type_Definition_Source: Cowardin, L.M., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildlife Service. 103 pp.

Attribute:

Attribute_Label: Wetland classification

Attribute_Definition: Classification of the Wetland

Attribute_Definition_Source: Cowardin, L.M., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildlife Service. 103 pp.

Attribute_Domain_Values:

Codeset_Domain:

Codeset_Name: Valid wetland classification code list

Codeset_Source: Photointerpretation Conventions for the National Wetlands Inventory, January 1995

Distribution_Information:

Distributor:

Contact_Information:

Contact_Organization_Primary:

Contact_Organization: Cooperator-Run Distribution Centers

Contact_Address:

Address_Type: List@www.nwi.fws.gov/Maps/distribution_ctrs.htm

Distribution_Liability: None

Standard_Order_Process:

Non_digital_Form: Hardcopy NWI wetlands maps at various scales, on diazo paper composited with USGS base map.

Digital_Form:

Digital_Transfer_Information:

Format_Name: Arc Export and Shapefile

Digital_Transfer_Option:

Online_Option:

Computer_Contact_Information:

Network_Address:

Network_Resource_Name:
ftp://ftp.nwi.fws.gov/arcdata/
ftp://ftp.nwi.fws.gov/shapedata/

Network_Resource_Name:
http://www.nwi.fws.gov/

Access_Instructions: Anyone with access to the Internet may connect to NWI's server via anonymous ftp and download available NWI digital wetlands data in Arc Export and Shapefile formats. Indexes for NWI hardcopy maps and digital data are also available. Digital wetlands data can be downloaded for 7.5 minute quadrangles throughout the USA. To access: ftp to the NWI server, login

as anonymous, enter your e-mail address at the password prompt, change to the arcdata directory for Arc Export data, or change to the shapedata directory for Shapefile data. Use the ftp 'get' command to transfer readme file for further instructions.
View the NWI home page by pointing your World Wide Web browser to the http address shown above.

Online_Computer_and_Operating_System: Sun Model 450 Unix server. Solaris 8 operating system.

Offline_Option:

Offline_Media: Arc Export Everything Tape - 8mm cartridge tape (5 Gb)

Recording_Capacity:

Recording_Density: 5

Recording_Density_Units: gigabytes

Recording_Format: tar

Metadata_Reference_Information:

Metadata_Contact:

Contact_Information:

Contact_Person_Primary:

Contact_Person: Andrew Paul

Contact_Organization: U.S. Fish & Wildlife Service, National Wetlands Inventory Center

Contact_Position: Cartographer

Contact_Address:

Address_Type: Mailing and Physical address

Address: 9720 Executive Center Drive
City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33702

Contact_Voice_Telephone: 727-570-5400

Contact_Facsimile_Telephone: 727-570-5420

Contact_Electronic_Mail_Address: Andrew_Paul@fws.gov

Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata

Metadata_Standard_Version: FGDC-STD-001-1998

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Metadata:

Identification_Information:

Citation:

Citation_Information:

Originator: Geospatial and Statistical Data Center, Alderman Library
Publication_Date: 19990527
Title: UNIQUE
Geospatial_Data_Presentation_Form: raster digital data
Online_Linkage: UNIQUE

Description:

Abstract:

These data can be used in a geographic information system (GIS) for any number of purposes such as assessing wildlife habitat, water quality, pesticide runoff, land use change, etc. The state data sets are provided with a 300 meter buffer beyond the state border to faciliate combining the state files into larger regions.

The user must have a firm understanding of how the datasets were compiled and the resulting limitations of these data. The National Land Cover Dataset was compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters and supplemented by various ancillary data (where available). The analysis and interpretation of the satellite imagery was conducted using very large, sometimes multi-state image mosaics (i.e. up to 18 Landsat scenes). Using a relatively small number of aerial photographs for 'ground truth', the thematic interpretations were necessarily conducted from a spatially-broad perspective. Furthermore, the accuracy assessments (see below) correspond to 'federal regions' which are groupings of contiguous States. Thus, the reliability of the data is greatest at the State or multi-State level. The statistical accuracy of the data is known only for the region.

Important Caution Advisory

With this in mind, users are cautioned to carefully scrutinize the data to see if they are of sufficient reliability before attempting to use the dataset for larger-scale or local analyses. This evaluation must be made remembering that the NLCD represents conditions in the early 1990s.

The Virginia portion of the NLCD was created as part of land cover mapping activities for Federal Region III that includes the States of Maryland, Delaware,

Pennsylvania, Virginia, West Virginia, and the District of Columbia. The NLCD classification contains 21 different land cover categories with a spatial resolutio 30 meters. The NLCD was produced as a cooperative effort between the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (US EPA) to produce a consistent, land cover data layer for the conterminous U.S. using early 1990s Landsat thematic mapper (TM) data purchased by the Multi-resolution Land Characterization (MRLC) Consortium. The MRLC Consortium is a partnership of federal agencies that produce or use land cover data. Partners include the USGS (National Mapping, Biological Resources, and Water Resources Divisions), US EPA, the U.S. Forest Service, and the National Oceanic and Atmospheric Administration.

Purpose:

The main objective of this project was to generate a generalized and nationally consistent land cover data layer for the entire conterminous United States. These data can be used as a layer in a geographic information system (GIS) for any number of purposes such assessing wildlife habitat, water quality and pesticide runoff, land use change, etc.

Supplemental_Information:

The land cover data files are provided as a 'Geo-TIFF'(on CDROM) or 8 bit binary files (from FTP site). The land cover data sets are single band raster images. The X/Y corner coordinates for Virginia are 1088700/ 1967100 (projection meters, center of Upper Left pixel).

The NLCD data for Virginia were clipped using county and independent city boundaries. For more information on this special processing see the Lineage section below.

Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 1986
Ending_Date: 1993
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: UNIQUE
East_Bounding_Coordinate: UNIQUE
North_Bounding_Coordinate: UNIQUE
South_Bounding_Coordinate: UNIQUE
Keywords:
Theme:
Theme_Keyword_Thesaurus: None
Theme_Keyword: Land Use/Land Cover
Theme_Keyword: Land Management
Theme_Keyword: Land Resources

Theme_Keyword: Imagery
Theme_Keyword: Land Characterization
Theme_Keyword: Land Cover
Theme_Keyword: Landsat
Theme_Keyword: Remote Sensing
Theme_Keyword: Satellite
Theme_Keyword: Space Imaging
Place:
Place_Keyword_Thesaurus:
U.S. Department of Commerce, 1977, Countries, dependencies, areas of special sovereignty, and their principal administrative divisions (Federal Information Processing Standard 10-3):Washington, D.C., National Institute of Standards and Technology.
Place_Keyword: North America
Place_Keyword: United States of America
Place:
Place_Keyword_Thesaurus:
U.S. Department of Commerce, 1987, Codes for the identification of the States, the District of Columbia, and the outlying areas of the United States and associated areas Federal Information Processing Standard 5-20; Washington, D.C., National Institute
Place_Keyword: Virginia
Place_Keyword: VA
Access_Constraints: None.
Use_Constraints:
None. Acknowledgement of the U.S. Geological Survey would be appreciated in products derived from these data.
Point_of_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Geospatial and Statistical Data Center, Alderman Library
Contact_Address:
Address_Type: mailing and physical address
Address: University of Virginia Alderman Library, Box 400129
City: Charlottesville
State_or_Province: VA
Postal_Code: 22904
Contact_Voice_Telephone: (434) 982-2630
Contact_Electronic_Mail_Address: geostat@virginia.edu
Browse_Graphic:
Browse_Graphic_File_Name: UNIQUE
Browse_Graphic_File_Description:
Browse_Graphic_File_Type:
Data_Set_Credit: Kelly Caylor

Data_Quality_Information:
Attribute_Accuracy:

Attribute_Accuracy_Report:

An accuracy assessment is done on all NLCD on a Federal Region basis following a revision cycle that incorporates feedback from MRLC Consortium partners and affiliated users. The accuracy assessments are conducted by private sector vendors under contract to the US EPA. A protocol has been established by the USGS and USEPA that incorporates a two-stage, geographically stratified cluster sampling plan (Zhu et al., 1999) utilizing National Aerial Photography Program (NAPP) photographs as the sampling frame and the basic sampling unit. In this design a NAPP photograph is defined as a 1st stage or primary sampling unit (PSU), and a sampled pixel within each PSU is treated as a 2nd stage or secondary sampling unit (SSU).

PSU's are selected from a sampling grid based on NAPP flight-lines and photo centers, each grid cell measures 15' X 15' (minutes of latitude/longitude) and consists of 32 NHAP photographs. A geographically stratified random sampling is performed with 1 NAPP photo being randomly selected from each cell (geographic strata), if a sampled photo falls outside of the regional boundary it is not used. Second stage sampling is accomplished by selecting SSU's (pixels) within each PSU (NAPP photo) to provide the actual locations for the reference land cover classification.

The SSU's are manually interpreted and misclassification errors are estimated and described using a traditional error matrix as well as a number of other important measures including the overall proportion of pixels correctly classified, user's and producer's accuracy's, and omission and commission error probabilities.

At the time of CD release (Summer 2000), the accuracy assessment was not complete. For the Region III accuracy assessment, please check the NLCD Website: <http://edcwww.usgs.gov/programs/lccp/nationallandcover.html>. The accuracy assessment numbers will be posted there around September, 2000.

While we believe that the approach taken has yielded a very good general land cover classification product for Region III, it is important to indicate to the user where there might be some potential problems. The biggest concerns for Region III are listed below:

1) Accurate definition of the transitional barren class was extremely difficult. The majority of pixels in this class correspond to clear-cut forests in various stages of regrowth. Spectrally, fresh clear-cuts are very similar to row-crops in the leaves-off data. Manual correction of coding errors was performed to improve differentiation between row-crops and clear-cuts, but some errors may still be found. As regrowth occurs in a clear-cut region, the definition of transitional barren versus a forested class becomes problematic. An attempt was made to classify only fresh clear-cuts or those in the earliest stages of regrowth, but there are likely forested regions classed as transitional barren and vice versa.

2) Due to the confusion between clear-cuts, regrowth in clear-cuts, Forested areas, and shrublands, no attempts were made to populate the shrubland classes. Any shrubland areas that exist in this area are classed in their like forest class, i.e.

deciduous shrubland is classed as deciduous forest, etc.

Logical_Consistency_Report:
An unsupervised classification algorithm was used to classify the mosaicked multiple leaf-off TM scenes. Aerial photographs were used to interpret and label classes into land cover categories and ancillary data sources resolved the class confusion. Further land cover information from leaf-on TM data, NWI data, and other sources were incorporated to refine and augment the "basic" classification.

Completeness_Report: All photo-interpretable data are mapped.

Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Each Landsat Thematic Mapper image used to create the NLCD was precision terrain-corrected using 3-arc-second digital terrain elevation data (DTED), and georegistered using ground control points. This resulted in a root mean square registration error of less than 1 pixel (30 meters).

Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:
Publication_Date:
Title:
Geospatial_Data_Presentation_Form:
Publication_Information:
Publication_Place: IF needed
Publisher: if needed
Type_of_Source_Media:
Source_Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: UNIQUE
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation:
Source_Contribution:
Process_Step:
Process_Description:
Source_Used_Citation_Abbreviation:
Process_Date:
Process_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Geospatial and Statistical Data Center, Alderman Library
Contact_Address:
Address_Type: mailing and physical address
Address: University of Virginia Alderman Library, Box 400129
City: Charlottesville
State_or_Province: VA

Postal_Code: 22904
Contact_Voice_Telephone: (434) 982-2630
Contact_Electronic_Mail_Address: geostat@virginia.edu

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: raster
Raster_Object_Information:
Raster_Object_Type: pixel
Row_Count: 23630
Column_Count: 13032

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Albers Conical Equal Area
Albers_Conical_Equal_Area:
Standard_Parallel: 29.5
Standard_Parallel: 45.5
Longitude_of_Central_Meridian: -96
Latitude_of_Projection_Origin: 23
False_Easting: 0
False_Northing: 0
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: Coordinate Pair
Coordinate_Representation:
Abscissa_Resolution: 30
Ordinate_Resolution: 30
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum 1983
Ellipsoid_Name: Geographic Reference System 80
Semi-major_Axis: 6378137
Denominator_of_Flattening_Ratio: 298.257

Entity_and_Attribute_Information:
Overview_Description:
Entity_and_Attribute_Overview:
NOTE - All classes may NOT be represented in a specific state data set. The class number represents the digital value of the class in the data set.

Water 11 Open Water 12 Perennial Ice/Snow

Developed 21 Low Intensity Residential 22 High Intensity Residential 23 Commercial/Industrial/Transportation

Barren 31 Bare Rock/Sand/Clay 32 Quarries/Strip Mines/Gravel Pits 33

Transitional

Vegetated; Natural Forested Upland 41 Deciduous Forest 42 Evergreen Forest 43 Mixed Forest

Shrubland 51 Shrubland

Non-natural Woody 61 Orchards/Vineyards/Other

Herbaceous Upland 71 Grasslands/Herbaceous

Herbaceous Planted/Cultivated 81 Pasture/Hay 82 Row Crops 83 Small Grains 84 Fallow 85 Urban/Recreational Grasses

Wetlands 91 Woody Wetlands 92 Emergent Herbaceous Wetlands

NLCD Land Cover Classification System Land Cover Class Definitions:

Water - All areas of open water or permanent ice/snow cover.

11. Open Water - areas of open water, generally with less than 25 percent or greater cover of water (per pixel).

12. Perennial Ice/Snow - All areas characterized by year-long cover of ice and/or snow.

Developed - areas characterized by high percentage (approximately 30% or greater) of constructed materials (e.g. asphalt, concrete, buildings, etc).

21. Low Intensity Residential - Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

22. High Intensity Residential - Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover.

23. Commercial/Industrial/Transportation - Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.

Barren - Areas characterized by bare rock, gravel, sad, silt, clay, or other earthen material, with little or no ""green"" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the ""green"" vegetated categories; lichen cover may be extensive.

31. Bare Rock/Sand/Clay - Perennially barren areas of bedrock, desert, pavement, scarps, talus, slides, volcanic material, glacial debris, and other accumulations of

earthen material.

32. Quarries/Strip Mines/Gravel Pits - Areas of extractive mining activities with significant surface expression.

33. Transitional - Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)

Forested Upland - Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); Tree canopy accounts for 25-100 percent of the cover.

41. Deciduous Forest - Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

Shrubland - Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

51. Shrubland - Areas dominated by shrubs; shrub canopy accounts for 25-100 percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrub cover may be less than 25 percent in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25 percent and shrubs cover exceeds the cover of the other life forms.

Non-natural Woody - Areas dominated by non-natural woody vegetation; non-natural woody vegetative canopy accounts for 25-100 percent of the cover. The non-natural woody classification is subject to the availability of sufficient ancillary data to differentiate non-natural woody vegetation from natural woody vegetation.

61. Orchards/Vineyards/Other - Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.

Herbaceous Upland - Upland areas characterized by natural or semi- natural herbaceous vegetation; herbaceous vegetation accounts for 75-100 percent of the cover.

71. Grasslands/Herbaceous - Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of

the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.

Planted/Cultivated - Areas characterized by herbaceous vegetation That has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

82. Row Crops - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

83. Small Grains - Areas used for the production of graminoid crops such as wheat, barley, oats, and rice

84. Fallow - Areas used for the production of crops that are temporarily barren or with sparse vegetative cover as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.

85. Urban/Recreational Grasses - Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Wetlands - Areas where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al.

91. Woody Wetlands - Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

92. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

Entity_and_Attribute_Detail_Citation:
NLCD Regional Land Cover Classification System Key Rev. 07/99
http:/fisher.lib.virginia.edu/nlcd/virginia_info.html

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Geospatial and Statistical Data Center, Alderman Library
Contact_Address:
Address_Type: mailing and physical address
Address: University of Virginia Alderman Library, Box 400129

City: Charlottesville
State_or_Province: VA
Postal_Code: 22904
Contact_Voice_Telephone: (434) 982-2630
Contact_Electronic_Mail_Address: geostat@virginia.edu
Resource_Description: Virginia Land Cover: UNIQUE
Distribution_Liability:
Although these data have been processed successfully on a computer system at the USGS, no warranty expressed or implied is made by the USGS regarding the use of the data on any other system, nor does the act of distribution constitute any such warranty.
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Format_Name: GeoTIFF
Format_Information_Content:
GeoTIFF is a standard for storing georeference and geocoding information in a TIFF 6.0 compliant raster file (uncompressed).
Digital_Transfer_Option:
Online_Option:
Computer_Contact_Information:
Network_Address:
Network_Resource_Name: UNIQUE
Fees: none

Metadata_Reference_Information:
Metadata_Date: UNIQUE
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Geospatial and Statistical Data Center, Alderman Library
Contact_Address:
Address_Type: mailing and physical address
Address: University of Virginia Alderman Library, Box 400129
City: Charlottesville
State_or_Province: VA
Postal_Code: 22904
Contact_Voice_Telephone: (434) 982-2630
Contact_Electronic_Mail_Address: geostat
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998

Generated by mp version 2.7.21 on Fri May 17 12:55:16 2002

Southwestern Pennsylvania Commission

UnifiedGIS

ECC Exhibit RJH-5

SPC maintains the following data layers within its GIS system for Southwestern Pennsylvania

GIS Coverage Descriptions

Abandoned Mine Land - Coal Mine Related
Agricultural Security Areas
Airports
Alliance for Aquatic Research Monitoring (Allarm)
Amusement Parks
Animal Equivalency Units
Attractions
Bedrock Geology of Pennsylvania
Bicycle/Pedestrian Network (SPC)
Boat Ramp Locations
Census Blocks (2000)
Census Block Centroids (1990)
Census Block Groups (1990, 2000)
Census Tracts (1990, 2000)
Campgrounds
Cemeteries
Colleges / Universities
Congressional Districts - PA State
Congressional Districts - Federal
Contacts, Dikes, and Fault Lines
County Boundaries
Crushed Stone Operations
Dam Locations
DCNR Trails
Drastic Scores to Ground Water vulnerability to Pollution
Environmental / Natural Heritage Areas
Fault Lines
Fish Species Occurrence Database
Fisheries Impacted by Acid Mine Drainage
Flood Prone Areas
Forests – State
Forest Density
Forest Type
Game Lands – State
Golf Courses
Ground Water Site Inventory Database
Historic Areas
Historic Sites
Hospitals
Hydrology - Stream, Lake, Pond Boundaries
Hydrology - Stream, Lake, Pond Areas
Industrial Parks
Land Cover - Satellite
Major Employers
Manage Surface Longwall Panels
Marina Locations
Military Sites
Municipal Boundaries
Oil and Gas Fields
Oil and Gas Wells
Open Spaces - Other
Parks - State, County, & Local
Park & Ride Lots
PA Conservation Gap Fish Habitat Model
Pittsburgh Coal Deep Mining
Pittsburgh Coal Seam Crop Line
Pittsburgh Coal Strip Deep Mining
Place Names - USGS
Public Water Supply Wells Database
Publicly Controlled Hunting Lands
Quality of Water (QW DATA) Database
Railroads
Railroad Crossings
Rivers
River Terminals / Barge Companies
Roads – All Federal, State, & Local
Sand and Gravel Operations
School Districts
Schools & Facilities
Senatorial Districts - PA State
Sewer Service Areas
Shopping Centers - Major
Slopes - Steep, 25% or Greater
Soils - Prime Agricultural
STATSGO Soils and MUID Database
Surface Water Sampling Sites
Traffic Analysis Zones
Traffic Signals
Transit Routes
Transportation Network / Major Roads
Upper Freeport Coal Deep Mining
Upper Freeport Coal Reserves (All)
Upper Freeport Coal Seam Crop Line
Upper Freeport Coal Strip Mining
USGS Quadrangle Boundaries
Warehouses - Public
Water Service Areas
Water Well Inventory
Watersheds
Wetlands – Major
Whitewater rafting/kayaking streams
ZIPCodes

Energy Conversation Council of Pennsylvania Surrebuttal Statement No. 3
Witness: Richard R. Hoch

4/1/08 Pgh FK
A-110172

BEFORE THE
PENNSYLVANIA PUBLIC UTILITY COMMISSION

In re: Application of Trans-Allegheny Interstate Line Company	:	Docket Nos. A-110172, A_110172F0002-F0004 and G-00071229

SURREBUTTAL TESTIMONY OF
RICHARD J. HOCH

Q. STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Richard J. Hoch and my address is 1099 University Drive, Dunbar, Pennsylvania 15431.

Q. WHO ARE YOU EMPLOYED BY?

A. I am an Assistant Professor of Geography and Regional Planning at Indiana University of Pennsylvania.

Q. HAVE YOU PREVIOUSLY SUBMITTED DIRECT TESTIMONY IN THIS PROCEEDING ON BEHALF OF ENERGY CONSERVATION COUNCIL OF PENNSYLVANIA?

A. Yes. My direct testimony was previously submitted in this proceeding as ECC Statement No. 3.

Q. PLEASE DESCRIBE THE PURPOSE OF YOUR SURREBUTTAL.

A. The purpose of my Surrebuttal testimony is to address the "rebuttal" testimony sponsored by TrAILCo witnesses Jack Halpern and Tim Gaul. My Surrebuttal reinforces the general opinions offered in my direct testimony as follows:

(1) I fully understand and appreciate the role that a Geographic Information System ("GIS") plays in a project such as the TrAIL project;

(2) Information and analysis supplied by GIS is only as accurate and precise as the data used in the system;

(3) GIS cannot provide information beyond the limitation of the dataset being used;

(4) TrAILCo used certain datasets that are not capable of providing the information presented as fact in its Route Evaluation Report and Environment report ("TrAILCo Report");

(5) TrAILCo should have only used GIS as a preliminary analysis method in the TrAILCo report;

(6) However, TrAILCo's preliminary analysis should have concluded that, due to the limited data sources required for this detailed analysis, alternative data sources must be identified and/or field surveys must be conducted; and

(7) It is the premature issuance of the report -- before such findings from the field surveys were included in the report -- that is the primary topic of concern to the Public Interest.

Q. HAVE YOU REVIEWED THE REBUTTAL TESTIMONY OF JACK HALPERN?

A. Yes, I have.

Q. WHAT IS YOUR REACTION TO HALPERN'S OPPOSITION TO AN ENVIRONMENTAL IMPACT ASSESSMENT?

A. In my original testimony, I advocated to the Pennsylvania Public Utility Commission (the "Commission") to require that this project adopt the Environmental Impact Assessment process. I urged for the Commission to mirror the analysis that is required by the NEPA process as a best management practice.

Q. WHAT DO YOU MEAN BY AN ENVIRONMENTAL IMPACT ASSESSMENT?

A. Environmental Impact Assessment is a process; an Environmental Impact Statement is a document. If the Commission were to require TrAILCo to adopt this process, then I stated that it was my opinion and recommendation that the Commission require TrAILCo to follow the same level of scrutiny and analysis that a NEPA-style Environmental Impact Assessment process would require.

Q. IS THERE ANYTHING PROHIBITING THE COMMISSION FROM REQUIRING TRAILCO TO PERFORM AN ENVIRONMENTAL IMPACT ASSESSMENT?

A. No. The Commission has apparent authority to require TrAILCo to complete an Environmental Impact Assessment process to effectuate the Commission's purpose and objectives. *See generally* 66 PA. CONS. STAT. ANN. § 501.

Q. SHOULD THE COMMISSION REQUEST TRAILCO TO COMPLETE A SOCIO-ECONOMIC PROFILE OF THE COMMUNITIES AFFECTED BY THE TRAIL PROJECT?

A. Yes. I believe it is the right thing to do for TrAILCo's environmental stewardship policy and for the Public Interest. I testified that it was appropriate for TrAILCo to perform a socio-economic profile of the study area in order to implement Environmental Justice in minority populations and low-income populations.

Q. WHAT IS ENVIRONMENTAL JUSTICE?

A. Environmental justice refers to the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws. Fair treatment means that minority and low-income groups should not bear a disproportionate share of the negative environmental impacts of government actions. (Bass, R., 1998. *Evaluating Environmental Justice Under the National Environmental Policy Act.* Environmental Impact Assessment Review. 18(1) pp. 83-92.).

Here the approval of the TrAILCo project by the Commission with the limited documentation provided would constitute a government action.

Q. HAS THE CONCEPT OF ENVIRONMENTAL JUSTICE BEEN RECOGNIZED AS A LEGITIMATE REGULATORY CONCERN?

A. Yes. Environmental Justice as a term and concept has been adopted by the Federal Government as part of the Environmental Impact Assessment process, as decreed by an Executive Order (Executive Order 12898 – February 11, 1994). Executive Order 12898 (E.O.) *Section 1-1. Implementation.* 1-101. Agency Responsibilities. states;

> To the greatest extent practicable and permitted by law, and consistent with the principles set forth [i]n 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 in the United States and its territories and possessions, the District of Columbia, the Commonwealth of Puerto Rico, and the Commonwealth of the Marian islands.

Executive Order 12898 can be found at: http://www.epa.gov/fedreg/eo/eo12898.htm.

Q. SHOULD THE COMMISSION REQUIRE TRAILCO TO COMPLY WITH THE PRINCIPLES OF ENVIRONMENTAL JUSTICE?

A. Yes. The analysis called for in E.O. 12898 is the best policy practice and only way that can adequately address PA Code § 57.75(e)(2) [The safety of the proposed HV line] and § 57.75(4) [The availability of reasonable alternative routes].

Q. SHOULD THE COMMISSION ADOPT TRAILCO'S APPARENT POSITION THAT SOCIO-ECONOMIC CONSIDERATION HAVE NO RELEVANCE?

A. No. To ignore socio-economic data in an environmental report is illogical. Halpern stated that "[t]he route selection study consciously did *not* take into consideration demographic factors such as income or race: it was a "*blind study.*" (Halpern 5-R at 9:11-12). Thus, Halpern essentially asserts that human beings are not part of the environment, and therefore, should not be examined as a critical component of environmental analysis.

Value judgments are inevitable in all environmental analysis, which is why it is a best policy practice to include data and information about socio-economic conditions in TrAILCo's analysis.

Below are some socio-economic indicators of Greene County, Pennsylvania. These data were collected by the Center of Rural Pennsylvania, a bipartisan, bicameral legislative agency that serves as a resource for rural policy within the Pennsylvania General Assembly.

(1) Poverty Rate:

- Greene County is the Pennsylvania County with the 3rd highest poverty rate - 15.7% (est. 2004).
- Greene County has the 2nd highest poverty rate amongst rural counties- (Behind Fayette County (16.9%), which borders Greene County to the east and is only a few miles from the TrAILCo project).

(2) Educational Attainment:

- 24.3% of the population does not have a high school education (PA state average: 18.1%).
- 47.6% of the population has a high school diploma or equivalent (PA state average: 38.1%).
- 15.9% have some college education or an Associates Degree (PA state average: 21.4%).
- 12.2% have a Bachelor Degree or higher (PA state average: 22.4%).

Q. CAN GIS APPROPRIATELY EVALUATE ENVIRONMENTAL CONDITIONS WITHOUT FIELD INVESTIGATIONS?

A. No. A GIS is one of many appropriate tools to use in environmental analysis. However, remote analysis of environmental conditions cannot be properly evaluated without field investigations. Please refer to earlier testimony and interrogatory responses regarding the

limitations of GIS and the documentation that describes limitations that accompanies all federally-produced datasets used as inputs into a GIS.

Halpern states,

> "It was used to identify major routing constraints, land uses and landscape features – uses for which GIS is most suited. Moreover, many of the detailed site specific concerns noted by ECC witness Hoch and others can only be clearly identified through field visits (with appropriate access rights), and many of these site specific impact concerns can be handled through design and engineering solutions."

TrAILCo Statement 5-R at 17:3-8. Here, Halpern acknowledges that many of the detailed concerns can only be addressed by field visits. He then states that site specific impact concerns can be handled through design and engineering solutions. This is relying on mitigation techniques without disclosure of potential impacts, as required by § 57.75(e)(3).

Halpern's use of GIS for siting purposes in seeking PUC approval over a dozen times merely equivocates the proper use of the datasets used in this evaluation and GIS in the TrAILCo process.

Q. IS TIM GAUL'S STATEMENT THAT TRAILCO'S APPLICATION USING GIS INFORMATION REASONABLY REPRESENTS RELEVANT ENVIRONMENTAL CONDITIONS ACCURATE?

A. No. Gaul states that,

> "data sources are not presented as an absolute assessment of the features they represent, but rather as a reasonable representation that is suitable for use when comparing between planning alternatives at this scale."

TrAILCo Statement No. R-19 (Testimony of Gaul). Gaul's use of 'scale' in this context is problematic. Gaul is essentially stating that the *size* of the project determines the relative *size* of what is to be, or not to be, considered as an area of concern. In this instance, Gaul

allows the dataset to dictate what is relevant and what is not. This is not a preferable approach to environmental analysis. What is best is to *know* what is relevant and seek the necessary data to investigate. Using Gaul's logic, as the size of a project increases, the level of detail of areas of concern decreases. This is not proper research design.

For example, if one was concerned with knowing how many feet of stream were to be potentially impacted by an activity, data required to furnish that precise information must be collected at a scale that captures data at the 1 foot interval.

In the TrAILCo report, the dataset used to identify surface waters was the National Hydrography Dataset. In earlier testimony I stated that the dataset was of a 1:100,000 scale. Gaul asserts that the scale use was of 1:24,000 scale. I have not inspected the data to which Gaul refers. However, the use of the 1:24,000 scale data does not diminish any of my previous testimony.

USGS 1:24,000 scale maps have a map to ground ratio of 1 inch representing 2,000 feet on the ground with a 90% chance of any line falling within +/- 40 feet.

The horizontal positional accuracy report of the metadata for the 1:24,000 National Hydrography Dataset (Hi-res NHD) states that the high-resolution NHD slightly decreases the positional accuracy of the USGS topographic quadrangle maps due to the digitization process.

The Hi-res NHD metadata states,

> For horizontal accuracy, this standard is met if at least 90 percent of points tested are within 0.02 inch (at map scale) of the true position. Additional offsets to positions may have been introduced where feature density is high to improve the legibility of map symbols. In addition, the digitizing of maps is estimated to contain a horizontal positional error of less than or equal to 0.003 inch standard error (at map scale) in the two component directions relative to the source maps.]

This means that the Hi-res NHD decreases the probability of horizontal positional accuracy by 6 feet (+/- 46 feet) then the probability of the horizontal positional accuracy of the standard, printed USGS 1:24,000 map product.

Even with the high-resolution NHD data, streams shorter than 1 mile may not have been collected/captured. Further, lakes/ponds smaller than 6 acres were not collected/captured.

As stated in Hi-res NHD metadata,

> Features found on the ground may have been eliminated or generalized on the source map because of scale and legibility constraints. **In general, streams longer than one mile (approximately 1.6 kilometers) were collected.** Most streams that flow from a lake were collected regardless of their length. Only definite channels were collected so not all swamp/marsh features have stream/rivers delineated through them. Lake/ponds having an area greater than 6 acres were collected. Note, however, that these general rules were applied unevenly among maps during compilation.

Hi-res NHD metadata document attached and located at: Http://nhdgeo.usgs.gov/metadata/nhd_high.htm (emphasis added). Both of these facts were verified by the U.S. Geological Survey National Hydrography Dataset User Support Desk.

Q. DO YOU HAVE ADDITIONAL CRITIQUES OF GAUL'S REBUTTAL?

A. Yes. My additional critiques are as follows:

- Page 9, Line 4: I believe that the report team did recognize the limitations of the NWI. This leads me to ask, why did the report not explicitly document these limitations about the dataset? Why were all of the metadata documents not referenced?
- Page 9, Line 15 ("Thus, the absolute accounting of their presence and extent is more important at the detailed engineering design and permitting stage, not for route selection."): The decision to ignore any detailed analysis of impacts until the design

and permitting stage rather than during the route selection process is putting the cart before the horse. Leaving future mitigation of potential unknown impacts does not, in my opinion, address § 57.75(e)(3). Please refer to my earlier testimony regarding the vintage of the NWI for the TrAILCo project area.

- Page 9, Line 23 ("simplified analysis"): It only requires simple analysis. The NWI is known to be an incomplete and unreliable data set. Its metadata lists its limitations. Please refer to my original testimony.

I fully recognize the role that wetland information plays in the standard route selection process. It is to be used as a broad, first look into documented and potential wetland sites. Only upon further extensive field review can all wetland sites be identified. The verification and identification of wetland sites must be identified before permitting is to occur.

- Page 11, Lines 13-23: Here again, Gaul incorrectly uses scale in his investigation. Gaul states that, in reference to the NLCD, "[i]t is a nationwide standard data source that is routinely used to characterize general land cover characteristics across landscapes." *Id.* The level of detail necessary for this type of environmental investigation is much greater than the ~30 meter pixel resolution that the NLCD provides. Gaul's use of the term 'landscape' is also problematic, as there is no scale-definition of landscape that I am aware of. Please refer to the limitations of this dataset as documented in the metadata document attached to my earlier testimony.
- Page 11, Lines 4-11: The NHD metadata clearly states that streams shorter than 1 mile may not have been collected/captured. It is, therefore, not possible to calculate the number of stream crossings -- even for comparing between alternatives -- without complete field inspection.

- Page 13, Lines 22-23: I agree that horizontal positional accuracy is very problematic in GIS datasets. Not only in the PaGWIS, but also in the other datasets used in the TrAILCo report. If TrAILCo was so reliant on the use of GIS datasets with problematic positional accuracy, why choose to not include the PaGWIS dataset of potential drinking water impacts?

Q. DOES THIS CONCLUDE YOUR SURREBUTTAL?

A. Yes. However, I reserve the right to file such additional testimony as may be necessary or appropriate.

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ATTACHMENT ECC-VII-3-F

Year	Agency	Project
2007	Public Service Commission of Virginia	TrAIL Project
2007	Pennsylvania Public Utility Commission	TrAIL Project
2007	Energy Resources Conservation Board (AB)	North-South Project
2007	State of Connecticut Siting Council	Oxford Substation Docket 304
2007	Scottish Ministers (UK)	Beauly-Denny Transmission Line
2006	State of Connecticut Siting Council	Best Management Practices Petition 754
2006	Maine Public Utilities Commission	Saco Bay Reinforcement Project Docket No. 2006-487
2006	Public Service Commission of the District of Columbia	Palmers Corners – Blue Plains Case 1044
2006	State of Rhode Island and Providence Plantations Energy Facility Siting Board	Southern Rhode Island Transmission Project Docket No. SB-2005-01
2006	National Energy Board of Canada	Juan de Fuca Project
2006	Pennsylvania Public Utility Commission	Wildwood Transmission Line Docket No. A-110150 F0031
2006	British Columbia Utilities Commission	Nk'Mip 63/13 kV Substation & Osoyoos 63 kV Transmission line
2006	State of Connecticut Siting Council	Trumbull Substation Docket 317
2005	State Office of Administrative Hearings (TX)	Johnson-Porter Line SOAH Docket No. 473-04-7105 Docket NO. 29420
2005	State of New Jersey Board of Public Utilities Commissioners	Cumberland Dennis 238-kV Evidentiary Hearing Docket No. EE04111374
	Public Service Commission of Maryland	Urbana Loop Transmission Line CASE NO. 9018
2004, 2005	State of Connecticut Siting Council	Middletown-Norwalk Project Docket 272
2004	State of Iowa Department of Commerce Utilities Board	Council Bluffs to Grimes Transmission line Docket Nos E-21521, E21622, E21645, E-21646, E-21625
2003	State of Connecticut Siting Council	Waterside Power Project Petition No. 617E
2003	Rhode Island Energy Facility Siting Board	E183 Transmission Line Relocation Project