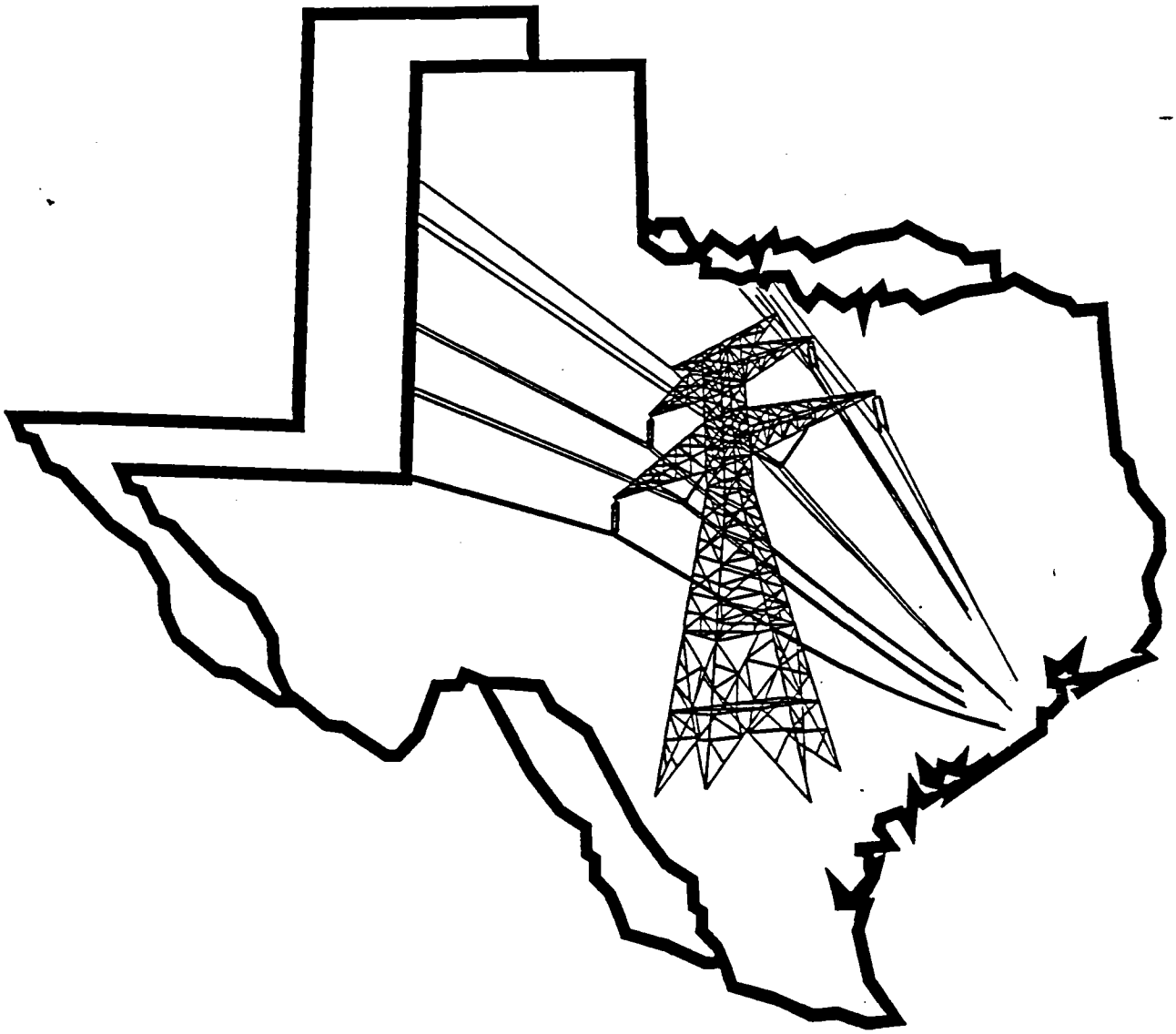
HEALTH EFFECTS OF EXPOSURE TO POWERLINE-FREQUENCY ELECTRIC AND MAGNETIC FIELDS

ELECTRO-MAGNETIC HEALTH EFFECTS COMMITTEE



PUBLIC UTILITY COMMISSION OF TEXAS

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PREFACE

The Electro-Magnetic Health Effects Committee has completed its initial examination of the literature and research involving electric and magnetic fields (EMF) and public health. This report is the result of three years of work by the Committee and represents a thorough study and analysis of the EMF issue. This report contains the Committee's review of EMF engineering and exposure assessment, epidemiologic studies, experimental studies, judicial issues, regulatory issues, and policy issues, and includes the Committee's recommendations to the Public Utility Commission of Texas. The conclusions and recommendations in this report represent the consensus of the Committee, and do not necessarily reflect the opinions of the Commission or the Commission Staff.

The Committee was originally proposed by a Commission task force that was organized to review the rules, practices, applications, and forms concerning transmission line certification in Texas. The task force identified numerous on-going studies concerning EMF and public health and believed that this issue required additional monitoring by qualified individuals. In February 1988, the task force recommended that the Commission appoint a Committee to study the EMF issue and report its findings annually to the Commission. The Committee met for the first time in January, 1989.

The Public Utility Commission of Texas recognized the increase in concerns regarding exposure to EMF and its potential effects on human health. The Commission agreed with the task force recommendations and on April 18, 1988, resolved that a Committee be appointed to study the literature and monitor the research concerning the possible health effects of exposure to electric and magnetic fields.

The Commission originally selected seven members and added an eighth member in September 1989. The members of the Committee represent the research community, the public health community, and electric utilities. They hold credentials in medicine, epidemiology, biology, engineering, health physics, bio-statistics, and public policy. The Committee members have served as volunteers and have not been reimbursed by the Commission for travel expenses or for the significant amount of time each member has devoted to this project. The Public Utility Commission of Texas owes the Committee members its sincere thanks and appreciation for the exceptional effort and commitment to this project.

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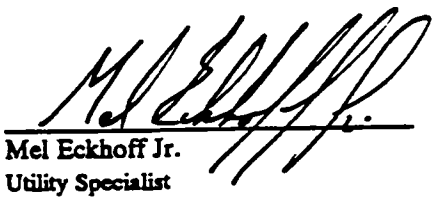

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

OVERVIEW

1. Introduction and Background

On April 18, 1988, the Public Utility Commission of Texas (PUC) established the Electro-Magnetic Health Effects Committee for the purpose of addressing the possible health effects of powerline-frequency electric and magnetic fields. The Committee was charged with the responsibility for researching the literature, monitoring on-going research, and reporting their findings annually to the Commission. This Committee was established as an independent review body which has served without compensation. Committee members were drawn from the research community, the Texas Department of Health, and suppliers of electric services. They are familiar with the scientific literature on electric and magnetic fields (EMF) and the methodology employed in this area. This report is the result of their efforts.

The report is divided into this Overview and major sections on the following topics: (1) Introduction and Background, (2) Engineering and Exposure Assessment, (3) Epidemiology of Health Effects and Exposure to EMF, (4) Experimental Studies, (5) Judicial Issues, (6) Regulatory Issues, and (7) Policy Issues and Options. In addition, appendices to the text are included.

Before the 1970's, health issues associated with electricity were limited to safety issues related to electrical shock. Then writers of a few reports from Eastern Europe suggested certain health effects in individuals exposed to electric and magnetic fields. In the mid-1970's, the State of New York began a 5-year, $5-million EMF research program. By the late 1980's, the scientific literature contained many EMF reports. The uncertainty inherent in such work has caused public concern because of the suggestion of cancer and other health effects.

Although public concern over EMF health effects has focused principally on transmission lines, such fields are produced by all electrical devices in everyday use.

Electric and magnetic fields are produced by voltage differences and current flow changes in electric transmission lines. Electricity generation and transmission is accomplished in three stages: (1) generation and passage through a step-up transformer, (2) transmission through high-voltage lines, and (3) passage through a step-down transformer and transfer to lower-voltage distribution lines. Alternating current (60 Hertz, or cycles per second) is standard in North America.

Electric and magnetic fields have been the subject of scientific study since the 19th century. Energy content from EMF is much lower than that from ionizing radiation (such as x rays) and is too low to cause heating effects. Even so, observations of some biological effects combined with findings from epidemiologic studies have increased the public's concern about possible human health effects. It is not clear which properties of the EMF environment among many should be measured, e.g., field intensity, duration of exposure, etc. In addition, it is clear that home appliances can produce magnetic fields as strong or stronger than those from transmission lines. Nonetheless, the public generally views involuntary exposure to be more of a health hazard than voluntary exposure. Research into this important issue is continuing largely through the efforts of the U.S. Department of Energy and the Electric Power Research Institute. Many uncertainties remain. This report concentrates on scientific, regulatory, and judicial aspects of EMF.

2. Engineering and Exposure Assessment

Demonstration of a cause-and-effect relationship between observed health effects and exposure to EMF is basically dependent on the accurate assessment of exposure to EMF and the resulting absorbed dose to cells, organs, and body. The electric and magnetic fields resulting from the everyday use of alternating current are complex, varying in properties such as wave shape, frequency, harmonic content, and transients (spikes). In vivo laboratory studies on animals and in vitro studies on cells, as well as epidemiologic studies, have failed to clearly identify any single field exposure parameter as a major agent in the induction of adverse health effects. The usual problems associated with applying data obtained from laboratory animals to humans are particularly important in the evaluation of EMF health effects. Furthermore, field measurements of exposure to electric and magnetic fields are by necessity limited to a determination of basic environmental properties. Most exposure assessments to date have been based on long-term average exposure rates. In this process, important data may not be recorded, and effects of exposure (dose) rate may be missed.

The Institute of Electrical and Electronic Engineers (IEEE) has established standards for methods used in measurement of EMF from power transmission lines. Development of standard methods for measuring EMF in other environments, such as residences, is

needed. Various instruments to measure EMF are available commercially. These are capable of reliable measurement of individual EMF parameters, but no one measurement system exists for completely characterizing EMF in the environment.

Regardless of the imperfect (and perhaps inaccurate) nature of current exposure assessment methods, data so obtained are essential to the scientific evaluation of possible health effects. In the laboratory, conditions of EMF exposure can be carefully controlled. Assessing the exposure of the public to EMF is, however, beset by a multitude of complicating factors that determine the effect of the fields as well as actual exposure. This situation causes confusion when an effort is made to apply causal relationships established in controlled laboratory studies to human populations.

In situations where it is difficult or impossible to make actual EMF measurements, exposure rate estimates can be generated by appropriate computer calculations. Reliable programs exist for calculation of EMF in the vicinity of power transmission lines, and more capable programs designed to calculate magnetic fields in the more complex residential indoor environment are under development.

When potential health effects of EMF from transmission lines are evaluated, background EMF needs to be considered. The average natural magnetic field of the earth at Texas latitudes, which is static in contrast to such fields in most "technologically enhanced" environments, is around 500 milliGauss (mG).

The natural electric field in the atmosphere is 130 volts per meter near the earth's surface. As in the case of the natural magnetic field, the natural electric field is essentially static, while electric fields due to use of electricity in the home or proximity to power transmission lines are alternating at a rate of 60 Hertz.

The magnetic field (flux density) directly beneath a 345-kV transmission line carrying an average load is about 130 mG. Design of transmission lines can strongly affect the magnitude of the EMF generated by the lines. Generally speaking, raising the height of a line above the ground reduces the strength of EMF outside the rights-of-way. Burying transmission cables, however, does not assure a significant reduction in the exposure to magnetic fields.

It has recently been found that the average magnetic field intensity within a U.S. home ranges from 0.5 to 1.0 mG and that average residential electric fields range from 5 to 20 volts per meter. Operating electric appliances, for example, an electric can opener, may generate a magnetic field up to 20,000 mG nearby. The normal combination of distance from an appliance and infrequent use reduces the possible significance of this source of EMF exposure.

3. Epidemiologic Studies of EMF Exposure

Epidemiology is the study of the incidence and distribution of human disease and injury. Epidemiologists organize the study of the complex process of disease causation in terms of the disease agent, the environment, and the host. Epidemiologic studies are organized into two types: descriptive and analytic. Descriptive epidemiologic studies explore patterns of disease in whole populations (correlational studies) or specific subgroups in a population (cross-sectional studies). Analytic studies characterize subjects that do or do not have a specific disease (case-control studies) or subjects who share a common risk factor for a disease (cohort studies). Of major concern in all types of epidemiologic studies is the potential for bias and confounding factors. Bias is avoided by stringently defining subject selection criteria and maintaining quality control over measurement procedures. Confounding factors are accounted for by understanding the complex interrelationships between exposure and disease.

In epidemiologic studies of EMF and cancer, scientists have attempted to define the incidence and distribution of health effects in populations exposed to electric and/or magnetic fields. However, the effectiveness of these studies has been limited by the use of indirect, imprecise, and/or inaccurate measures of exposure. Uncertainty in exposure measurements is magnified by the absence of a plausible biological effect mechanism in any EMF-cancer association and by the difficulty of formulating a dose-response relationship. No proper measure of EMF exposure has been defined.

The exposure assessment methodologies currently in use are surrogate or indirect measures of exposure, exposure models, and field measurements. Indirect EMF exposure measures which have been used are wire configuration codes, job titles, and census codes (indicators of occupation). Exposure models based on historical data have been used to project exposure values. Field measurements provide screening information for short-term exposures but may not give good indications of average long-term exposures.

Various categories of wiring configurations have been devised by researchers to substitute as measures of exposure in homes. These include, for example, very high current configurations (VHCC)

and ordinary low current configurations (OLCC), both of which are dependent on the proximity of a dwelling to specific types of powerline wiring configurations.

Job titles have also been used as surrogates for exposure to EMF. Occupational epidemiologic studies have focused on telecommunications workers, electrical engineers, and other occupations considered to be exposed to EMF. However, actual exposures in these groups were largely unknown and were assessed on the basis of exposure categories. One study attempted to determine actual occupational exposures by using portable dosimeters for measuring individual exposures to EMF. Even within a single job category, considerable variability in field exposures was found.

Field measurements have shown some promise when used in comparison with wiring configurations and for linking spot measurements to 24-hour average magnetic fields. However, a single 24-hour measurement may yield imprecise results. A model based on measurement data seems to provide a better index than the measurements alone.

Exposure assessment studies are also subject to confounders. Subjects may be exposed to carcinogens in the environment as well as to EMF. A true confounder will be related to both EMF and cancer. In one EMF study, traffic density was studied as an indirect measure of exposure to vehicle emissions and benzene (both related to cancer), and a statistically significant association between cancer and traffic density was found. In another study the "wire code effect" was most pronounced among females, older children, those living in multi-family housing, disadvantaged persons, and those whose mothers smoked during pregnancy. These outcomes indicate the importance of other factors in correlation with cancer risk.

In order to assess the results of epidemiologic studies of EMF, one must consider both internal and external validity. Internal validity is concerned with the criteria, procedures, attention to confounders, and chance that go into designing and performing a study. External validity is concerned with how the results of a study can be generalized and whether the study addresses the causal nature of the association between EMF and disease.

After confirming that a study is internally valid, epidemiologists follow several guidelines to aid in the determination of external validity. These include strength, consistency, specificity, temporality, dose-response gradient, biological plausibility, coherence of evidence, and effect of intervention. The magnitude of risk ratios or strength, for example, can be used to partially assess the external validity of an epidemiologic study. Risk ratios less than 2.0 are likely to be affected by bias or confounding; risk factors greater than 5.0 are more likely to reflect a true increase in risk. A causal hypothesis may be further strengthened when experimental evidence is available. Laboratory or experimental studies completed under controlled conditions provide valuable data regarding the generality of a hypothesis that is being considered.

An essential component of epidemiologic evidence in the study of human cancer and its causes is time trends for various cancers. In the United States, such data have been compiled by the American Cancer Society back to 1930. Data for the years 1930-1987 for various cancer sites including lung, leukemia, brain, breast, and total cancers for males and females and adults and children were compiled for this report. One of the important findings in these data is the effect of the shifting age distribution of U.S. population. Total cancer mortality rates appear to have doubled over the last 50 years, but when adjusted for changing age distributions, the rate increases by only about 20% over the same time interval. An increase in the size of older age groups necessarily leads to an increase in the number of people dying of diseases associated with old age, which include cancer. In addition, the total age-adjusted cancer mortality rates change dramatically when lung cancer deaths are subtracted. Mortality rates for cancer minus lung cancer have remained nearly constant for males and have actually decreased for females over the period of study.

Of particular importance to this study are the findings for male adult leukemia and brain/central nervous system (CNS) cancers, and male and female childhood leukemia, brain/CNS, and total cancers. Mortality rates for all these cancer sites were undergoing substantial increases prior to the exponential growth period (beginning in 1945) in U.S. electric power consumption. In general, mortality rates for these cancers began to level off or decline after the period of rapid increase in electric power consumption.

In previously published reviews of EMF epidemiologic studies which are cited in this report, results from both residential and occupational settings were analyzed. Two initial studies of EMF and disease were done by Wertheimer and Leeper in 1979 and 1982. In the former study, the authors found a excess of high-current wiring configurations near former homes of children who had died of cancer, and in the latter study, the authors found an increase in adult cancer mortality associated with high-current wiring configurations. Other EMF reviews included a study of residential childhood leukemia and exposure to EMF with a summary odds ratio of 1.33, a residential exposure study of

childhood cancer of the CNS with an odds ratio of 2.44, an occupational exposure study for leukemia with a risk estimate of 1.18, an occupational exposure study for myeloid leukemia with a risk estimate of 1.46, and several other occupational exposure studies. Many of the studies mentioned in the reviews cited in this report lacked precise assessments of exposure. One study for male breast cancer among telephone workers reported a standardized incidence ratio of 6.5, which has been interpreted to lend support to the proposal that EMF increases cancer risks by interfering with melatonin production. However, melatonin production may be independently affected by the shiftwork of the subjects.

Childhood cancers associated with residential EMF exposures were explored in five studies. Two of the five studies exploring associations of EMF with total childhood cancers reported significant associations with odds ratios of 2.22 and 2.10. With regard to childhood leukemia, none of the studies showed a consistent association with EMF, but two produced odds ratios of 2.35 and 2.10. The findings for childhood tumor of the CNS were also inconsistent with only one study producing a moderately elevated odds ratio of 2.86.

Adult cancers associated with residential exposures were evaluated in five studies. Only two out of the five studies produced significant results. One reported an association of EMF with total cancer (odds ratio of 1.28) and associations for lymphomas, cancer of the CNS, uterus, and breast. The other reported a significant association with lung cancer. In addition, four of the five studies reported weak associations of EMF with adult leukemia.

This report evaluates occupational EMF studies in association with all cancer sites, leukemia, tumors of the CNS, melanoma, and other cancer sites. In addition, this report evaluates several studies which examined the associations between paternal occupations having potential for EMF exposures and childhood cancers and adverse effects on reproduction. This report also evaluates 15 studies of the association of occupational exposures with all cancer sites. Because of differences in definitions, methodology, and other inconsistencies, it was impossible to determine any causal relationships. Leukemia incidence among occupationally exposed individuals has been given the most attention, and results for this site are suggestive of a causal association. Among 15 studies of leukemia and EMF, several have yielded weak, but statistically significant, results. However, problems with confounding factors and inaccurate exposure assessments limit the usefulness of the leukemia results. Cancer of the CNS has also received increased attention. Studies of this site have been beset with the same problems as the leukemia studies, and half of the studies have produced inconclusive results. Significant results were reported for associations of job categories with malignant melanoma and eye cancer, but not for testicular cancer. Finally, three of six studies of childhood cancer/paternal occupation which were evaluated in this report showed significant results. Five studies were completed on adverse reproductive effects, and in three of these studies statistically significant associations were found with spontaneous abortion, frequency of abnormal pregnancy, and congenital malformation.

Adding to the public's concern over cancer and EMF has been the misuse of cancer epidemiologic data. Because cancer incidence data are generally unavailable, time-trend studies are usually based on mortality rates. Mortality rates can be expressed in several ways, but in order to present a true picture, two factors affecting such presentations must be taken into account: data must be age-adjusted to account for shifting age distributions in the population of the U.S., and improvements in medical care which have dramatically decreased the proportion of the population dying from infectious diseases must be heeded. Consideration of these two factors produces a much different view of the present importance of cancer as a cause of death. In addition, no positive correlation is seen between age-adjusted cancer mortality trends and increases in U.S. electric power consumption, which one would expect to see if an EMF relation exists. (Lung cancer, of course, remains at the top of the list for cancer mortality.)

Utilizing cancer statistics, risk managers in Federal regulatory agencies seek to achieve protection of public health and the environment while responding to the requirements of the Office of Management and Budget, defending the technological and economic feasibility of a proposed action, and following legislative mandates. Ultimately, risk managers respond to specific problems based on assessments which are formed using accepted scientific criteria. However, several models for risk assessment have evolved. New approaches to risk assessment are being formulated which recognize the importance of a scientific approach to risk decisions.

Historically, the attention surrounding EMF grew out of public concern in the 1960's for the aesthetic and nuisance problems related to high voltage transmission lines. Reports in the late 1960's and early 1970's by Soviet scientists concerning possible health effects of EMF changed the focus of public concern. Western scientists failed to confirm the Soviet findings, except that a study in Denver in the late 1970's seemed to confirm the earlier studies. Negative findings did not ease public concerns.

In conclusion, much disagreement exists over the relationship, if any, between EMF and disease. Available epidemiologic evidence has produced limited conclusions. Findings related to leukemia remain suggestive, and associations with cancer of the CNS and other cancer sites are inconclusive.

In order to improve the quality of future EMF epidemiologic studies, the Committee offers several recommendations. The exposed population must be well defined. There should be more than one reference cohort. More work needs to be done to accurately assess the complex nature of EMF exposure. New EMF measurement technologies need to be explored. The relationship, if any, between residential wiring configurations and EMF exposure needs to be studied. The biological basis of any health effects in humans needs further study. Epidemiologic results should provide guidance for new experimental studies. Special care must be taken in future studies to control for confounders and to avoid internal inconsistencies.

4. Experimental Studies of EMF Exposures

The Committee examined the results of numerous laboratory experiments, comprising in vivo (alive) studies of EMF effects on animals (e.g., rats, baboons) and in vitro (test tube) studies at the cellular level. These studies focused on animal behavior, cancer initiation and promotion, developmental and growth effects, endocrine system and immunity and cell-cell (membrane) interactions.

While the quantity and quality of EMF research have improved dramatically in recent years, the EMF effects data base is still in a state of infancy when compared to the research literature on other potential environmental exposure risks. Although laboratory studies generally provide a greater opportunity to control extraneous variables than do epidemiologic and field studies, many opportunities still exist for sources of error to enter into even the best designed study. It is possible that the EMF literature, like most scientific literature, contains false positives and false negatives. The Committee has found that the scientific literature on EMF contains results of laboratory studies that were performed under a variety of exposure metrics (e.g., frequencies, field intensities, exposure duration, earth's static magnetic field). Thus, the inconsistencies and contradictions of study findings may be due to unknown errors and/or the numerous aforementioned laboratory conditions. This circumstance makes it difficult to sort through the literature, interpret the evidence, and draw definite conclusions with respect to EMF effects.

Nonetheless, the Committee believes that, based on its evaluation of the laboratory and epidemiologic literature, there is at this time no conclusive evidence to suggest that EMF due to electric power transmission lines poses a human health hazard. The Committee believes that this conclusion is basically corroborated in other EMF literature summaries and background reports prepared by expert scientific and research panels.

The following observations can be summarized on the basis of the studies evaluated by the Committee:

The interaction of variables which control actual exposure to EMF is poorly understood. Undoubtedly, the inconsistencies and contradictions found in the scientific literature are due, at least partly, to this fact.

Under certain circumstances, animals and humans can detect and avoid electric fields. However, no research to date has presented any conclusive evidence that these fields, detected or not, produce any deleterious and/or long lasting impacts on animal or human behavior.

One of the current models for carcinogenisis involves two steps, initiation and promotion. The initiation step involves direct or indirect permanent damage to the cell's genetic material (DNA). Ionizing radiation and certain chemicals have been identified as cancer initiators. Promotion is characterized by uncontrolled cell growth (tumor formation) after exposure to an initiator, which causes or allows the expression of genetic damage. Neither electric nor magnetic fields are energetic enough to cause damage to DNA, and it is generally accepted that power frequency fields are not cancer initiators. However, scientists have suggested that EMF may be a cancer promoter. No firm conclusions can be drawn on the promotion theory at this time. Hypotheses are only now being advanced. Additional information is clearly needed.

Most of the EMF studies reviewed by the Committee found no teratogenic effects during embryonic development or during postnatal growth. A few studies do show effects. Some show effects only under "pulsed" fields, which are not normally associated with 60-Hz alternating current transmission. Certain studies show effects using one animal strain, but no effects with another. A high incidence of effects is observed in the controls of various studies, making interpretation of the data difficult. Overall, these laboratory studies tend to lead to the conclusion that there is no proven detrimental effect on prenatal development or postnatal growth from exposure to EMF.

It has been suggested that exposure to EMF can affect animal immune systems. Whole-animal studies

have not shown such an effect, but certain cellular studies indicate possible effects. Hypotheses need to be developed and tested before any definitive conclusion can be drawn.

Several studies suggest that EMF exposure causes changes in the function of animal endocrine systems. For example, reduction in night-time melatonin production and alteration of biological rhythm have been recorded in animals exposed to 60-Hz fields. Numerous physiological effects due to melatonin reduction have been hypothesized, but the potential health effects due to such reduction needs further investigation.

Many in vitro studies have shown no effect on cells exposed to EMF, while others have shown positive effects. Although the results of these studies are complex and inconclusive, a growing number of positive findings imply that, under specific conditions, EMF can produce cellular changes. For example, levels of calcium which is involved in the regulation of numerous physiological processes have been shown to be affected in several test systems. The significance of these results is unknown.

Although effects have been observed at the cellular level, with most being attributed to changes occurring at the cell membrane, the actual biophysical and/or biological mechanism is unknown. Various mechanisms have been postulated, but all are speculative. More research is needed to evaluate these mechanisms. If a mechanism is established at the cellular level, this will support the positive laboratory and epidemiologic studies.

5. Judicial Issues

Although the EMF health effects issue is still actively debated in scientific circles and the public press, it has been a factor in several types of judicial proceedings for some time. An increase in judicial proceedings on this issue is expected. As used here, "judicial" includes siting, zoning, condemnation, and tort proceedings. The PUC is concerned only with transmission line siting considerations.

An early concern about EMF health effects was expressed during Public Service Commission hearings in New York in the mid-1970's on a proposed 765-kV transmission line. Since then, many proceedings have involved presentation of evidence relative to the EMF health effects question. Over 200 proceedings involving EMF cases related to power transmission and substations have been reported. Of more local interest, nine Texas electric utilities have reported one or more proceedings where EMF or other health effects issues were raised.

Review of the information available on EMF-related judicial proceedings shows that, to date, little weight has been given to EMF health effects claims by objectors, intervenors, and plaintiffs. Due to public perceptions of potential hazards and scientific interest, however, the EMF issue is assured continued involvement in judicial proceedings. To respond to these continuing concerns, the utilities are developing strategies including keeping up with EMF-related research, complying with regulations regarding the planning and siting of facilities, surveying public awareness about EMF health effects, and developing public education and information programs.

6. Regulatory Issues

As powerline-frequency transmission grids have expanded, so have the health concerns of those citizens living, working, or going to school close to power lines. Some citizens believe that regulations are necessary to protect public health. Such regulations are being contemplated and enacted in some states.

Several approaches to regulations can be considered for controlling power line placement. Specific circumstances may dictate which approach is used. When adopting regulations, a government agency may use a standard (an acknowledged criterion for comparison) or a limit (a specified level which is restrictive). Other options are to use a guideline (an optional standard or limit) or a criterion statement (usually a document for making informed decisions about regulations). Ordinarily, regulations which are protective of health are based upon health risk assessments, an approach which takes into account all the evidence and weighs benefits versus risk to assign an acceptable level of safety.

If health-based regulations designed to protect the public or exposed workers are contemplated for transmission line siting, explicit health data are required. At present, however, no such data exist, nor is there any other rational approach for setting exposure regulations to protect public health. Before occupational regulations can be adopted, a consistent health effect must be found which is related to a measure of EMF exposure (such as frequency, intensity, or time). The necessary basic EMF data would then be combined with the so-called "healthy worker" criteria which define possible exposure time on the job and basic human physiological quantities. Similarly, biological evidence, quantification of dose, and risk assessment information must be available to set regulations for populations. Any regulations written in the absence of the mentioned data would offer no protection and could possibly hinder further investigations into real health effects.

International organizations such as the World Health Organization, the International Radiation Protection Association, and some countries (the United Kingdom and Australia) have addressed the EMF issue. These groups have found that the scientific data suggesting health effects due to long-term environmental EMF exposure are not persuasive.

In the United States, the Congress, several federal agencies, a few institutes, and some national associations have performed some preliminary work on the EMF issue. Although the federal government has no clear mandate or authority to take regulatory action concerning 60-Hz EMF and the existing evidence does not compel immediate action, some federal action has occurred. Congress has hosted hearings to collect testimony on the issue; the U.S. Environmental Protection Agency has conducted a review of EMF scientific literature; the U.S. Department of Energy has maintained a strong research program in the area of basic EMF science; the U.S. Department of Transportation is evaluating "maglev" trains; and several other agencies have maintained a more limited involvement in the area. Organizations like the National Council on Radiation Protection and Measurements and the American National Standards Institute have not pursued the issue at a rigorous level but may do so when the scientific results become less speculative. Associations like the National Association of Regulatory Utility Commissioners and the Conference of Radiation Control Program Directors have urged greater federal involvement.

At present, the only generally applied national standard for EMF is the National Electric Safety Code, which deals with reducing shock hazards from transmission lines. This code is not intended to provide protection from possible long-term health effects due to chronic exposure.

Because of the lack of federal leadership on the EMF issue, the states have responded individually. The result is varied and lacks consistency. The states' responses have fallen into four categories: (1) take no action, (2) study and report on the issue, (3) fund research, and/or (4) use regulatory authority to establish standards. At least one common thread runs through these efforts: In the absence of a firm dose-response relationship or intended results, no method for evaluating the benefit of EMF standards is available. In the body of this report, the Committee details the actions taken by seven states.

Texas powerline siting problems are similar to those in other states. In some cases siting permit applications have been contested, and the applicants have been taken to court. A health-based standard would have simplified the siting process by providing design criteria to achieve compliance. Without clear evidence upon which to develop a health-based standard, the Commission may make use of Section 23.44 of the Public Utility Regulatory Act, which addresses new construction. Section 23.44 is based on American National Standards Institute (ANSI) and National Electric Safety Code (NESC) standards. If EMF standards are issued by ANSI and/or NESC, the Commission could readily adopt them as guides. A question remains, however, about regulatory jurisdiction over city-owned utilities in siting questions. Another option for the PUC is to defer to the Texas Department of Health which has the ultimate responsibility for developing statewide health standards.

7. Policy Issues and Options

The current status of scientific evidence regarding EMF health effects is unclear. There is no definitive indication that EMF exposure can affect health, and there are no data that establish convincingly that it does not. In fact, as is often the case in situations involving very low probability cause/effect relationships, it may not ever be possible to prove an effect or the lack of an effect.

With respect to the EMF health effects issue, state legislatures find themselves in a quandary. Acceptance of false positive conclusions may result in a significant expenditure of taxpayers' money and divert attention from efforts to seek the true source of any increased risk. By contrast, not acting on false negative conclusions is likely to be interpreted by the public as irresponsible disregard for citizens' safety. Therefore, it seems reasonable to expect legislatures to actively support efforts to resolve the conflict.

Regulatory agencies normally address scientific uncertainty, such as the EMF health effects question, through procedural mechanisms similar to those used in the courts and legislatures. The details of the mechanisms vary considerably depending on the nature of the regulatory agency and its legislative charter. Political pressures to "do something" about the EMF issue may result directly or indirectly in the search for regulatory relief, especially if no action is achieved at the judicial or legislative levels.

In at least 17 states, legislative or administrative agencies have formally considered the possibility of health effects as a result of EMF exposure. Responses range from dismissal of the question due to lack of evidence (Wyoming) to codification of formal EMF limits in transmission lines (Florida). Courts and legislatures are actively considering actions in several states.

Different responses and their rationales are tied to different views of what constitutes the key problem in the EMF debate. There have been at least four different ways to define the EMF "problem", each with distinctive views of the scientific evidence, of the proper role for science to play, and of the proper perception of risk. More importantly, each definition carries a policy prescription along with it. In the absence of a conclusive body of scientific findings that would provide a firm grounding for deciding which of the four ways of constructing the problem is the most appropriate, one is left to decide largely on the basis of pre-existing beliefs and values that each of us brings to the EMF issue.

In this instance, the values of experts alone may provide too narrow a basis for legitimating one definition of the problem over others. Recognizing this limitation, the Committee recommends that, until science can provide a clearer path, state officials should engage the public in open discussions of both the evidence to date and the public values that influence its interpretation.

CONCLUSIONS AND RECOMMENDATIONS

The following are the Committee's overall conclusions and recommendations regarding standards, siting criteria, research, and public education.

1. Standards

1.1 Conclusions

The Committee has examined much of the current EMF scientific literature. Many epidemiologic studies have investigated the possibility of an association between disease and residence near installations transmitting electricity. Epidemiologic studies have most frequently investigated the possibility of an association between various types of cancer and exposure to EMF. To date, the results from these epidemiologic studies have been inconsistent and inconclusive.

The results of the laboratory studies evaluated by the Committee are also inconsistent and in some cases inconclusive. However, it is apparent that under specific exposure conditions, biological changes do occur. It appears that many variables (e.g., frequency, intensity, exposure duration, field orientations) can affect the results of these studies, which undoubtedly play an important part in the inconsistencies reported in the literature.

The Committee believes that, based on its evaluation of the existing EMF research, the evidence at this time is insufficient to conclude that exposure to EMF from electric power transmission lines poses an imminent or significant public health risk. In general, the Committee's evaluation is corroborated by other EMF literature summaries and background reports.

The Committee concludes that at present there is insufficient evidence regarding human health effects of EMF to provide the basis for a health-based standard. The Committee can find no reason to create arbitrary numbers to use as a desired level of exposure, because the use of such numbers cannot be argued or defended on the basis of scientific evidence. The primary objective of the Committee is the protection of public health, and the Committee can find no scientific argument to support standards, either through guidance or through regulatory criteria.

The Committee has reviewed various state EMF standards. However, the use of numbers for an arbitrary standard in the absence of scientific justification sets a de facto risk level which is not supported by available evidence. Use of such numbers, which is strictly political, can generate a false sense of security, diverting resources from evaluating a genuine risk associated with some other environmental factor.

The Committee concludes that regulatory activities should be divorced from the EMF issue, at this time, and that the Public Utility Commission of Texas (PUC) take action regarding the EMF health effects issue only when, or if, action can be justified on a public health basis. If such action is required, the Committee concludes that the issue be referred to the Texas Department of Health (TDH), since the PUC does not have authority over all EMF sources (e.g., appliances, home wiring). The TDH is the state agency with authority in health matters.

1.2 Recommendations

The Committee recommends that neither the PUC nor other state authorities attempt to set EMF standards through guidelines, regulations, or legislation.

Should new evidence emerge establishing a clear association of human health effects from EMF exposure, justifying promulgation of standards, the Committee recommends that the EMF issue be referred to the Texas Department of Health.

2. Siting Criteria

2.1 Conclusions

The Committee concludes that at present, the existing criteria used by the PUC for siting transmission lines appear to be adequate. The Committee concludes that a plan for engineering interventions is not warranted at this time. The Committee noted that "prudent avoidance" in siting of transmission lines has been the de facto philosophy in the PUC criteria since 1976, by avoiding population centers, historical sites and existing facilities. Matters of safety and rights-of-way criteria have influenced the selection of routes. Based on current evidence, the Committee finds this approach adequate and acceptable.

2.2 Recommendations

The Committee recommends that the PUC continue its policy of de facto "prudent avoidance" in the siting of transmission lines. We further recommend that, at this time, the PUC not expand existing routing criteria to include concerns regarding health effects of EMF exposures.