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ABSTRACT

I have conducted many studies dealing of the effects of electromagnetic fields (EMFs) on cells, animals, and human beings. My purpose is to address the question whether there will be a health risk at the Benson property as a consequence of chronic exposure to the EMFs from the Maudsland-Molendinar powerline (Powerline).

The issue of the health hazards posed by chronic exposure to these fields is evaluated using the appropriate scientific evidence in the context of the rules and principles of a model for evaluating the implications of scientific experiments for human beings. Four models have been used by the courts and other tribunals to ascertain the societal implications of scientific evidence. The choice of the model utilized is a crucial factor in resolving the issue of health risks on the Benson property.

In my implementation of the four models, I used scientific data available in the open peer-reviewed scientific literature that was produced under conditions free of the fact or appearance of misconduct. Almost all research supported or controlled by the power industry did not meet these conditions and therefore was not considered. Had it been considered, because it was almost entirely negative, it would not have affected my

conclusions. I also did not consider the opinions of expert committees because they were largely controlled by the power industry, and were devoid of analysis.

The *Safety Model* is used to set exposure levels for an agent based on health considerations, for example maximum permissible levels for food additives or safe drinking water. The safety levels are usually set by means of a procedure in which laboratory animals are exposed to various levels of an agent of interest, and the level that is tolerated by the animal without any overt biological change is elucidated. Once that level has been identified, the agent may be authorized for use at a level 100 times lower than the level studied in the experiment. This safety factor is chosen in recognition of the uncertainties that attend extrapolating the results of short-term animal experiments to long-term human exposures. If the available honest scientific literature is evaluated within the context of the Safety Model, the unambiguous conclusion is that the exposure conditions on the Benson property and in the Benson home are a serious and significant risk to health.

The *Medical Model* is ordinarily used to decide whether a particular drug or device is safe for use in patients, and whether it is efficacious for the particular purpose suggested by the sponsoring company. The drug or device is tested in laboratory experiments to ascertain whether it has the power to affect the system of the body it would ultimately be used to treat in patients. Additional studies are done to determine whether the drug or device is likely to produce side-effects, which are any unintended effects. A side-effect is presumed to create risk, and all drugs and devices have side-effects. The issue, therefore, becomes one of weighing the benefits against the risks

due to the side-effects. The Medical Model normally employs scientific facts produced in laboratory studies and in clinical studies.

If the Medical Model were used to evaluate the honest peer-reviewed scientific literature dealing with the biological effects of EMFs, it would clearly be concluded that exposure conditions on their property can produce side-effects because virtually every system of the body has been shown in laboratory studies to be affected by EMFs. It is a question for the court whether these risks are balanced by any potential benefits flowing to either the Bensons or to society at large. A complicating factor in this analysis is that the EMF exposure on the Benson property is involuntary. This consideration could mean either that the Medical Model is inapplicable, or that it should be applied even more strictly to protect the health of those exposed to the EMFs for whom the benefits
are minimal but he risks are palpable.

The *Fairness Model* is used to evaluate the environmental exposure experienced by the general public under conditions where they have made no conscious decision to be exposed to the agent. A typical application of the model is zoning cases where use of adjacent property may create health risks for nearby residents. The issue under this model is whether situations roughly similar to the one under consideration have resulted in harm to other people. The evidence considered is that provided by pertinent epidemiological studies, which may be sufficient to warrant relying on a general dispositive principle such as the choice to err on the side of safety. The model best fits the situation where there is an inequality between the two parties regarding the quality and extent of knowledge regarding a matter that affects both parties, as where one

party is knowledgeable concerning biological and engineering aspects of powerlines, and the party who may be affected by the activity in some way has little or no such knowledge. The residential epidemiological studies, if evaluated under this model, lead to the clear conclusion that the exposure produced on the Benson property will be a health hazard because at least 11 studies have found an increased risk of one or more kinds of cancer, usually cancer of the blood or brain, due to powerline fields; the percent increases range from 53-420%.

The *Toxicological Model* is typically used by the industry trade groups, unions, and governmental agencies that regulate workplace exposure to potential toxic agents. Individuals exposed in the workplace are typically healthy adults, and restrictions on the exposure levels characteristically reduce industry efficiency. Consequently, the basic philosophy is that clear and definite evidence of actual harm is needed to warrant the imposition of exposure limits. The evidentiary criteria for a conclusion of harm using this model is extremely high. In the prototypical case the burden is met by a showing of a causal relationship between toxic exposure and illness that would be apparent even to a layman. The numerous epidemiological studies reported in the literature that deal with workplace exposure to electromagnetic fields suggest, but do not conclusively prove in a convincing fashion beyond dispute that the exposure levels on the Benson property will definitely be a health risk.

QUALIFICATIONS AND EXPERIENCE

I began my research on the biological effects of electromagnetic fields (EMFs) in 1964. Since then I have worked full-time conducting studies to determine the effects of EMFs on cells, tissues, animals, and human beings. This work was performed at the Veterans Administration Medical Center, Syracuse, New York between 1964 and 1981, and at the Louisiana State University Health Sciences Center, Shreveport, Louisiana from 1981 until the present. The results of my research have been published in more than 120 peer-reviewed scientific articles, and in three books that I authored or co-authored. A list of my scientific publications is included in my Curriculum Vitae (Appendix 1). I am a member of the major scientific societies that are pertinent to the study of the biological effects of electromagnetic fields and related subjects such as statistics and epidemiology. I founded a scientific journal devoted to the study of the biological effects of electromagnetic fields which has been published continuously for more than 20 years.

I am currently a full tenured professor in the Department of Orthopaedic Surgery, and the Department of Cellular Biology and Anatomy at Louisiana State University Health Sciences Center, Shreveport, Louisiana. I am also a professor in the Department of Biomedical Engineering, Louisiana Tech University, Ruston, Louisiana. In addition to research, my academic duties include teaching medical students, graduate students, and orthopaedic residents. In various courses and lectures, I teach methods of experimental design for conducting human, animal, and cellular studies, cell biology, physiology, electrophysiology, immunology, molecular biology, nonlinear analysis,

statistical analysis, philosophy and ethics of science and medicine, and medical jurisprudence.

I have served on numerous committees at the Louisiana State University Health Sciences Center, and have been president of the Faculty on two occasions. I have approximately 10 years' experience serving on the Review Board for Human Experimentation, including 5 years as chairman, and I am familiar with the ethical, scientific, and legal principles governing human experimentation. I have designed and conducted numerous human experiments including but not limited to experiments aimed at understanding the effects of electromagnetic fields on the electrical activity of thebrain of human beings.

I am admitted to the Bar in the states of New York and Louisiana. During the past 25 years I have testified as an expert witness regarding the biological effects of electromagnetic fields in the United States, Canada, and Australia.

PURPOSE AND APPROACH

I will address the question whether there will be a health risk at the location of the Benson property as a consequence of chronic exposure to the electromagnetic fields (EMFs) from the Maudsland-Molendinar powerline (“basic issue”).

There are no general objective principles of risk management, only individuals functioning within a value system who hold opinions regarding applicable principles. Every opinion regarding risk due to EMFs from powerlines is founded in significant part on a value system. The impact of the value judgments on the basic issue is plain to see. Powerlink undoubtedly does not want to subject the Bensons to environmental conditions that predisposed them and their family to cancer or some other disease. Just
as obviously, the Bensons do not want to endure exposure that would have such a consequence. However, the Bensons’ interest in avoiding disease is surely greater than Powerlink’s interest that they should do so. Were it otherwise, Powerlink could bury the powerline, thereby erring on the side of safety and completely obviating the basic issue regarding risk at the Benson property, which arises as a consequence of an economic decision to build an overhead powerline.

I do not intend to offer the court any opinions regarding the management of risk that are based on my personal values because I believe that choice belongs to society at large, as delineated and implemented by the courts. Instead I will explain and discuss the four models for assessing human health risks based on scientific data that are available to the court, and the inferences regarding risk at the Benson property that flow

from each model. I will also give an opinion, with supporting reasons, regarding which of the four models best fits the situation at the Benson property.

SCIENTIFIC METHODS AND SCIENTIFIC FACTS

It is important that the court be apprised of the nature and limits of scientific facts and the accepted methods by which they ordinarily are evaluated, because it is the reliable scientific evidence upon which all four models for assessing health risks from EMFs are based. In this section, therefore, I will discuss two general methods by means of which the results of individual experiments become accepted as *individual facts*, and the method by which they are generalized so as to become *general facts*. The court will see that one method produces specific facts that are more reliable than the other, and that both methods produce specific facts that are more certain than their respective general facts. My goal in this section is to apprise the court of precisely what it is that science can do and can't do, and thereby provide a proper context for evaluating the quality and character of the evidence pertinent to the issue of the effects produced by powerline EMFs.

In subsequent sections I will describe (1)!the nature of scientific publications, and identify the properties that indicate what publications are honest and credible, (2)!the electromagnetic field at the Benson property, (3)!the scientific evidence that is pertinent to that situation, (4)!the four models that have been used to evaluate the implications that scientific data have for society at large, and the inferences that can be made within each model from the available scientific evidence.

For the purposes of the EMF issue, we can take science to mean a collection of facts adduced by a particular set of methods. Disagreements regarding facts can arise because of the manner in which the method was executed. For example, an experiment

one expert believes shows that stunted growth occurred in mice exposed to simulated powerline EMFs may be rejected by another expert who thinks the study was done improperly because of the way the mice were housed or treated, and consequently that the conclusions of the study are not warranted (it is not a fact that the EMF caused stunted growth in that study).

Disagreements can also occur because of the way that generalizations are formed. For example, powerline experts have vigorously opposed accrediting such generalizations as “Powerline EMFs can affect the immune system in animals,” or “Powerline electromagnetic fields can alter the growth of animals,” while other experts have affirmed these statements as scientific facts with equal vigor. It is the method by which these two kinds of facts are normally established that is discussed in this section.

Two fundamental kinds of scientific studies are pertinent to the issue of EMF bioeffects. Typically, scientific facts are the results of a measurement or observation, or they are inferences from a *laboratory experiment*. In some cases the inferential fact arises from another kind of a study, an *epidemiological study*. It is crucial that the court be aware of the difference between a laboratory and an epidemiological study with regard to their probative value and scientific worth.

Individual Laboratory Studies

The purpose of a laboratory study is to justify a statement of the form “x caused y,” where, for our purposes, “x” is an EMF of a particular frequency and strength, and “y” is a change in some biological endpoint that was measured under specific conditions in

the subjects of the experiment (Figure 1). For example, the subjects may have been rats exposed to an electric field of 5000!volts/meter for 1 month, and the biological endpoint measured may have been the stress hormone called corticosterone. If the average corticosterone levels in the animals exposed to the EMF was determined to be higher than the corresponding average in the controls, and if the difference could not be ascribed to chance (usually assessed using a statistical test), then it could be concluded that the EMF caused the change in corticosterone in that experiment.

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(unable to reproduce diagram)

Figure 1. Basic design of a laboratory study (top) and epidemiological study (bottom).

The complexity of living systems is such that myriad factors can affect them, and any such factor is labeled a *cause.* Thus, “The EMF caused the change in corticosterone” means that the change in the average corticosterone level would not have occurred under the conditions of the experiment but for the presence of the EMF.

It is always the case in laboratory experiments that “x” is neither necessary nor sufficient. In other words, other factors besides EMFs can alter corticosterone levels, and there are different conditions under which the corticosterone level would not be not changed by the field. These facts parallel those that occur within ordinary experience. For example, even though there is a relationship between taking antibiotics and the presence of infection, an antibiotic is not always a sufficient cause of a cure for the infection because not everyone who takes the antibiotic in a similar amount becomes cured. Moreover, the antibiotic is not a necessary cause because not every cured person used antibiotics. Thus, even at the level of basic experiments, it is always the case in laboratory studies that “x” is neither necessary nor sufficient, and that the strongest causal statement that can be rationalized is that “x” is a sufficient cause in some cases. If the meaning of “cause” is disrespected in the process of evaluating health risks from powerlines, the result is often complete confusion.

Generalizing Individual Laboratory Studies

In an experiment involving rats, suppose "x" was a specific amount of EMF exposure of a particular gender and strain of rats, "y" was the observation of a particular change in the immune system, and "x caused y" was justified in the experiment by means of a statistical test. Clearly, if "x caused y" is true, it follows that "x can cause y" is also true.

Suppose that we contemplate the meaning of "x can cause y" where "x" now represents a different amount of EMF exposure than was used in the actual experiment.

The conclusion that "x can cause y" was originally rationalized by reference to the observation that "x caused y," but it would be incorrect to say "caused" in the context of the different EMF because that experiment has not been performed. If it were performed, the observed change in the immune system might be different. In fact, for any "x" other than that used in the study, "x can cause y" would be untrue because the statement is specifically applicable to a particular "x" and "y," and not based on the results of an experiment.

How, then, are the results of studies generalized so that the results may be used to state a proposition applicable in situations other than the precise circumstances of the original study? Such an inductive conclusion is justified when a sufficient number of additional studies yield mutually consistent results. The induction may then be expressed by removing the terms qualifying the subject and the predicate. The result is that the assertion becomes "X can cause Y," where "X" is any of a broad range of types of EMFs and "Y" is the immune system (not restricted to specific immune parameters).

Thus, reasoning in biology normally proceeds from a group of specific laboratory observations to an inductive statement, the generality and applicability of which depends on, among other things, the quality, quantity, and degree of relevance of the component studies.

A biological generalization also depends on the individual making the generalization, and therefore scientists' views of the truth of a biological judgment will differ, because individual views will differ regarding the importance of various items of evidence used to justify the generalization. One factor will be differing views regarding

the choice of scientific reports to be considered. Another factor is the weight the individual scientist affords particular studies. Perhaps the most important factor is the degree of certitude a scientist implicitly incorporates in his inductive generalization.

Some scientists instinctively demand many studies and a high degree of certitude, while others find a general cause-and-effect relationship on the basis of relatively fewer studies.

Individual Epidemiological Studies

The basic design of most epidemiological studies pertinent to the issue of health hazards due to powerline EMFs is shown in Figure 1. Further details regarding the design of experimental studies are given in Appendix 2, Report No.1.

Epidemiological studies typically begin with the identification of a group of subjects that have already exhibited the disease the investigator wishes to study as potentially being a result of EMF exposure. For example, when my colleagues and I studied the relationship between living near a high-voltage powerline and suicide, we began by first identifying all the people who lived in a certain geographical area who had committed suicide within a particular period of time (as listed in the records of the coroner).

The next step in an epidemiological study is to identify an appropriate comparison group. In our suicide study, for example, we identified a suitable comparison group by first determining the age and gender of each of the suicide victims, and then randomly choosing a group of living subjects whose composition was

similar to the suicide group. We then went to the home of each suicide victim and each person in the comparison group and measured the power-frequency magnetic field. We were thus able to compute what percentage of the suicide victims were exposed to high fields and compare it to the corresponding value in the control group, which served as a frame of reference to determine whether the percentage in the suicide group was unusually high.

In an epidemiological study, for several reasons, it is not logically possible to rationalize a causal connection. First, there was no initial randomization of subjects into the two groups, and consequently it is not possible to establish that the control group was appropriate for the purposes of assessing whether it was the EMF exposure experienced by the diseased subjects that caused the elevated disease level. It is likely that the control group differed in other factors besides the factor of not exhibiting the disease being studied, and it is logically possible that some such difference between the two group was the responsible cause of any observed differences in percentages. In the suicide study, for example, it could have been the case that the addresses in the control group were at locations where an unknown factor in the air or the water was different compared with the locations where the suicide victims lived, and that it was the difference in the unknown factor that was responsible for the suicide, and not the relatively high magnetic fields we found at those addresses.

Epidemiological studies eschew the term “cause” and employ the euphemism “association” which is the word used to describe the observation of a statistically significant difference when the proportions of two groups were compared. Thus, in our

suicide study we concluded that increased levels of power-frequency magnetic fields were “associated with” the occurrence of suicide, not that the fields “caused” the suicides.

Epidemiological studies have other intrinsic shortcomings when considered as vehicles for generating specific scientific facts. For example, once a diseased group has been identified, it is almost always impossible to reconstruct the actual amount of exposure that a subject had during the time period prior to exhibiting the disease. Consequently, the cumulative dose of the putative causal agent can never be established. In my suicide study, for example, we measured the magnetic field one meter from the front door of the residence, and one meter above the ground. We regarded those values as a surrogate for “exposure to powerline EMFs.” It could be argued, however, that the surrogate was not appropriate because it was essentially a snapshot value and might not have characterized the long-term exposure that occurred prior to the suicide.

Interminable disputes occur whenever epidemiological studies are used as a source of scientific facts in a dispute having significant economic overtones. In the context of health risks from EMFs, for example, the power industry typically wants the court (or the government agency, affected landowner, or any of many other kinds of interested parties) to conceptualize the epidemiological studies as indeterminate, unclear, or unreliable, and its experts emphasize their scientific limitations. It is important for the court to recognize, however, that these problems infect every epidemiological study that has ever been performed or will be performed, because they

are rooted in the logical and scientific nature of an epidemiological study. Such studies are never definitive and never justify the assertion of a causal connection.

In view of the severe limitations of epidemiological studies it is reasonable to ask why they are ever performed. The simple reason is that in almost every instance there is no alternative method for obtaining information about what happens to human beings and the factors that cause those diseases other than to employ the epidemiological method. It is the best method available to science for producing cause-like knowledge in cases where the subjects are human beings and the observed manifestation is some form of disease. Also, epidemiological studies are usually less expensive than laboratory studies.

The question that ought to be the focus of inquiry in the context of an expert who attacks the available epidemiological evidence regarding the disease-promoting properties of powerline EMFs should be on the question of what class of epidemiological studies (other than those involving EMFs) the expert regards as the paradigm for a proper epidemiological study that could serve as the basis for generating acceptable epidemiological facts. The truth is there does not exist any class of epidemiological studies whose quality and character exceeds those that involve the study of EMFs. This being the case, the available choices are to either reject epidemiology as a source of scientific facts (which many scientists probably have done), or to accept the import of the present EMF epidemiological studies showing that powerline EMFs are certainly associated with increased disease levels.

Generalizing Epidemiological Studies

Generalizations based solely on epidemiological studies are not possible. Generalizations can, of course, be asserted by individual scientists or groups, but there are invariably powerful voices in opposition. The more usual situation is the incorporation of the results from laboratory studies in a kind of generalized analysis aimed at stating a general fact. In other words, the generalized fact associated with epidemiological studies is invariably a hybrid, based on both epidemiological and laboratory facts. The only possible exception of which I am aware is the link between cigarette smoking and disease.

THE VALIDITY OF SCIENTIFIC PUBLICATIONS

Introduction

If evidence produced by science is to be used to evaluate the health risks on the Benson property due to the EMFs of the Maudsland-Molendinar powerline, a determination is needed of the characteristics of the available reports and studies that indicate they are sufficiently dependable to be taken into consideration. Generally, the reports and studies should have undergone peer review. It is therefore essential to understand the process, and its strengths and weaknesses.

The analysis that I will present in later sections regarding the hazards on the Benson property will be based on peer-reviewed publications, but I have not included all peer-reviewed publications. Instead I have largely ignored peer-reviewed publications that described research controlled by the power industry. I also discounted almost completely the opinions regarding health risks from powerlines proffered by expert committees. My reasons for rejecting the work of industry scientists and expert committees is explained in this section.

Peer Review

Scientists have long recognized the need for a process by which the validity of scientific data can be assessed. The process that developed to meet this need is one of the most important and pervasive features of science, peer review, the essential features of which are universal. After an experiment is conducted and evaluated by the investigator, he submits a written description of the work to a scientific journal that

specializes in reviewing, evaluating, and publishing such research. The editor of the journal sends copies for review to persons he deems knowledgeable regarding the subject of the study.

The reviewers, whose identities are not disclosed to the authors, comment on the scientific merit of the work described in the manuscript, including the adequacy of experimental design, the techniques of measurement, the appropriateness of statistical analysis, the methods and procedures used for handling the research subjects, the relationship among the stated aims of the study, and the data obtained, the interpretation given, and the conclusions stated.

It is important to recognize that the reviewers do not consider either the method by which the study was funded or the ultimate reason it was performed when evaluating the merits of a particular report. Since the method of funding a study is not a factor in the review process, the information often is not disclosed. Medical journals typically require disclosure by the authors regarding whether the authors have received anything of value in connection with the research described in the article. Such a standard of disclosure, however, is still rare in basic science journals in biology. In many cases, research studies that were performed under the control of the power industry, or were performed by investigators who received something of value in connection with their research is not disclosed.

The reviewers provide a written evaluation of the manuscript, and the editor either accepts or rejects the manuscript, or accepts it conditioned upon the inclusion of specific changes. An accepted manuscript appears in the journal in due course and

becomes a permanent addition to the corpus of science, because journals are maintained in perpetuity in archival scientific libraries. Such a manuscript is said to have been “peer reviewed,” meaning the work has met a minimum standard within the particular scientific discipline regarding the quality of the work described therein, as determined by the journal editor.

The peer-review process confers no express or implied warranties regarding the truthfulness, importance, or general acceptance of the methods or data in the report. Nevertheless, the peer-review process serves its intended purposes of screening for obvious errors in methodology or reasoning, and for ensuring the work is not simply a rehash of previously performed work. Peer-reviewed studies are the means by which scientific knowledge is normally disseminated, learned, opposed, improved, corrected, or rejected. It is the peer-reviewed publication that experts normally look to as the source of scientific knowledge, and therefore as the basis of scientific judgments

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Industry-Controlled Research

The source of funding of a scientific experiment is not a factor in the peer review of a manuscript because the review process is limited to scientific considerations. Nevertheless, the nature of the privity between the author of a scientific study and a party that fund the work is an important issue that affects the believability of the study.

A contract is a method of funding research to provide knowledge desired by the funding party. Data obtained pursuant to a contract is owned by the funder, which therefore has the right to determine the data's disposition and the extent of access that

will be permitted. An investigator performing contract research may be an employee of a company, a private research organization, a national laboratory, or a university.

Investigators working under contract may be permitted to submit some of their work for peer review, depending on the sponsor's needs and desires. The sponsor, however, may have concerns regarding patentability, competitor advantage, or potential liability, and consequently may encourage secrecy regarding some or all of the study results. The lack of academic freedom to publish any data one chooses is a well-understood aspect of contract research. In agreeing to perform contract research, an investigator acknowledges that the primary goal is the satisfaction of the contract, not contribution to the corpus of public knowledge in science.

The overwhelming majority of research funded by the power industry in the United States and Europe, is funded by means of contract. Under such an arrangement the experimental design is not disclosed to other interested scientists, and data generated during the study is not disclosed except for the data the company may choose to disclose. The organization that has been most active in funding contract research dealing with the potential health hazards of powerline EMFs is a power-industry trade organization headquartered in Palo Alto, California called the Electric Power Research Institute (EPRI). EPRI began funding powerline research in 1976.

EPRI has never disclosed how much money it has spent on research dealing with health impacts of powerline EMFs, but my estimate is that the total probably exceeds $500 million. Virtually all of this research is secret in the sense that the design of the experiments to be performed and the data obtained were not released to the scientific

community except in very limited instances where tiny portions of the data were released. In almost all such instances, the material released broadly supported the industry position that present exposure patterns of the public to powerline EMFs is completely safe. It is even difficult to obtain copies of the highly polished summaries of the few reports that are made available, because EPRI's price for their reports is exorbitant.

During my career I have directly experienced virtually every species of scientific misconduct that is possible under these circumstances. In cases where the results of the experiments were adverse to the power industry, no data was disclosed. There were instances in which adverse data was withheld and data showing no effects due to the EMF was disseminated. There were instances in which the experimental design of the study was changed after the data was adduced thereby making negative what otherwise would have been a positive study.

Even in instances where I have no direct evidence of misconduct, I discounted the publications controlled by the power industry those results because it cannot be reasonably presumed that the data the power industry permits to be disclosed is representative of data that it has not disclosed.

One aspect of power company-supported research that directly indicates its unreliability is the dichotomy of its results with respect to similar research that it does not control. One can divide the world literature dealing with the biological effects of EMFs into two categories, *positive* and *negative*. By *positive* I mean that the investigator reported that some biological endpoint in the laboratory system (or group of diseased

subjects) under study was affected by the applied EMF. In the second group of experiments, the *negative* studies, the investigator did not find that the EMF studied caused a biological effect (hence, found no evidence to suggest that EMFs might be a health hazard). It is an empirical fact that for industry-controlled research the percentage of *negative* reports is vastly greater than the percentage of *positive* reports, but that for research that was not controlled by the power industry the percentage of positive reports is vastly greater than the percentage of negative reports.

A negative study represents a scientific failure because it amounts to an experiment where an investigator found nothing, despite the expenditure of time and money. With one minor exception, a negative study has no probative value (notwithstanding its usefulness in lay forums where it tends to suggest safety) because it simply means that the investigator may have looked in the wrong place at the wrong time in the wrong way, like someone who drills a dry well.

What could explain the huge excess of failures over successes among the studies supported and controlled by the industry when the ratio is completely reversed for studies that were not controlled by the industry? The very best that could be said for the education and experience of the power company investigators is that they equaled those of investigators who found positive results; consequently it is not possible to explain the data on that basis. In my judgment, the explanation is the obvious one, namely that the investigators were selected because of their predisposition and bias towards producing a negative result.

Research Funded by Grants

Another way of funding scientific research is the grant, a method whereby the goals of the research are chosen by the investigator, and the primary interest of the granting organization is the contribution to public knowledge within the particular branch of science. Under a grant, data produced in the experiment is ordinarily required to be disclosed because the experiments are paid for by taxes and the knowledge generated therefore belongs to society at large. In these cases, there is no danger that the investigator's grant will be terminated if he publishes data that has implications which are potentially inimical to the interests of some organization. In fact, the converse is true. If the investigator fails to obtain publishable data most granting agencies would decline to renew the investigator's grant on the basis that he had failed to be productive.
The typical grantee is an academician who is expected to perform research and publish as a condition of academic employment.

In the United States, the National Institutes of Health is the major funding agency for such research. A condition for accepting a grant from the National Institutes of Health is that essentially every aspect of the study, including experimental design,
descriptions of the work performed, and even the raw data obtained during the study must be made available to any interested scientist, or any interested person. For example, after I received a grant from the National Institutes of Health to study the effect of powerline magnetic fields on the immune system of mice, a law firm that represented the power industry requested a copy of my experimental design, and I provided it. Subsequently, others requested copies of the data I produced during the study, and I also provided the data.

Expert Committees

Since the inception of disputes involving the issue of health risks from powerline EMFs, more than a dozen expert committees of scientists have proffered opinions regarding the likelihood of health risks from exposure to the EMFs from powerlines. Several aspects of the nature and activity of these expert committees indicate they are an inappropriate and unreliable source of knowledge regarding the risks posed by powerline EMFs.

First, the goal of the expert committees was to reach a consensus of the committee members. But a consensus has practical value only if it was formed by a representative group of individuals, because only then could anyone confidently regard the committee's opinion as representative of all scientists knowledgeable in the matter. I am generally familiar with the composition and background of the members of the EMF expert committees. In virtually every case, many or most of the members were employees or consultants to the power industry. This being the case, it could hardly be considered that their opinions were fair and unbiased. The point is not that the opinions of power-company employees or consultants are necessarily without merit. The point is that it would be unfair to rely on opinions of individuals who are economically tied to the power industry to evaluate the health risk at the Benson property when they do not appear in court to be properly examined. There is simply no substitute for vigorously examining an expert under oath to determine exactly why he holds a particular opinion.

The difficulties posed by an uncritical reliance on the bare opinion of the expert committees goes far beyond the problem that such committees were largely composed of experts from the power industry having clear or apparent conflicts of interest. Their method of analysis, insofar as it can be gleaned from their pronouncements almost always relies almost exclusively on results of experiments controlled by the power industry. The experts on the committees know or should know that such work is frequently dishonest and not deserving of acceptance of what it states on its face.

Further, the method of analysis almost always completely ignores the results of experiments performed by investigators, myself and many others, who were not controlled by the power industry and where the research results have obvious implications that were far different than those they drew from the industry reports.

With few exceptions, it has proved impossible to examine in detail the reasoning of the members of the expert committees who have opined regarding health risks because the power industry has not made them available in forums where such examinations might be possible.

In the last analysis, the metaphor applicable to expert committees who have opined generally regarding health risks from the EMFs arising from powerlines is not that of a wise, gray-haired father giving sage advice to his children whom he expects will react with an unquestioning gratitude. Rather, the situation is more like a group of salesmen selling a product in anticipation or gratitude for a reward. I have engaged many of the experts who have served on expert committees in dialogue and debate, and have come to the conclusion that their reasoning and the extent of their knowledge

does not warrant their conclusions. However, any stranger to these committees, and to the long history of the dispute that they purport to resolve, would have no basis for accepting their opinions without at least requiring them to explain the method by which they were formed.

MODELS FOR ASSESSING HUMAN HEALTH RISK

I have explained how honest scientists perform experiments pertinent to the issue of whether EMFs can cause biological effects in exposed subjects. I have also explained the method by which science ordinarily forms generalizations in the scientific domain based on the results of a collection of related experiments (for example, individual experiments dealing with the immune system leading to a general statement about the effects of EMFs on the immune system). I pointed out that both good-faith and bad-faith disputes can take place at each level of analysis because the results of individual experiments or the implications of a group of experiments are never certain or free from the possibility of error. I distinguished the laboratory experiment and the epidemiologic experiment and discussed their intrinsic differences in probative value. The discussion highlighted the futility of criticizing epidemiological experiments involving EMFs solely on the basis of characteristics that are intrinsic to that kind of experiment. I pointed out that any attempt to assess whether the EMFs at the Benson property will constitute a health risk must be addressed on the basis of scientific evidence that has two essential properties — competence and honesty. Ordinarily, the application of peer review to the description of an experiment is the minimum criterion for indicating to scientists and laymen that a particular experiment was performed competently. But that the process cannot indicate whether it was performed honestly. I gave reasons why the research controlled by the power industry is not honest, and reasons why the more-or-less naked opinions of expert panels that have opined regarding health risks from powerline EMFs lack credibility. Finally, I explained to the court that an attempt to form

an opinion regarding the health risks at the Benson property based on the competent, honest scientific evidence presently available inevitably involves the incorporation of value judgments, and therefore that the basic question presented to the court involves consideration of whose values and what values will be incorporated in the ultimate answer. It is appropriate and proper to inquire how similar situations have been resolved in other forums.

What are “similar situations?” They are instances in which a decision must be made on the basis of more or less purely scientific evidence, where the consequence of the decision will necessarily apply to society at large. That is, they are instances in which scientific facts are taken out of the purely scientific domain and applied for the benefit of all society, both scientists and non-scientists. Every such application of science is problematical to one degree or another because the underlying science is always less than certain, and because powerful human emotions and desires are invariably inextricably involved in the decisional process. Even so, the process is performed routinely and, indeed, it is the intent to do so that is the main reason thatmost laboratory and epidemiological experiments are performed in the first instance.

At least four models for carrying out this review and adjudicatory process can be delineated, each with its own set of rules, economic setting, and potential impact. The *Safety Model* is used where a judging authority has the responsibility to set exposure levels for an agent based on health considerations. The model is often used in an economic setting such as when an authority sets maximum permissible levels for food additives or other substances ordinarily consumed by the general public. The same

model is used in non-economic settings such as when an authority sets safe drinking water standards or standards that govern the maximum allowable amount of pesticide residues in food consumed by the general public. The safety levels are usually set by means of a procedure in which laboratory animals are exposed to various levels of the agent of interest, and the level that is tolerated by the animals without any overt biological changes is elucidated. The animal species, duration of exposure, and biological endpoint measured typically depend on the particular agent under consideration, but the general approach is quite clear. Once an exposure level has been identified that does not produce a change in the measured biological endpoint ("the no-effects level") the agent may be authorized for human exposure or consumption at a level 100 times lower than the no-effects level determined in the experiments. The *safety factor* of 100 is chosen in recognition of the uncertainties that attend extrapolating the results of short-term animal experiments to long-term human exposures. Thus, if 50 units of a food additive or a contaminant found in food or water does not affect laboratory animals, then ordinarily the agent could be added to or tolerated in food or water at a level of 0.5 units. Ordinarily, in the Safety Model one does not parse the nature of individual biological effects that might be found in animals, but rather assumes that <u>any</u> biological change induced by the agent is adverse or potentially adverse, and all changes caused by the agent are sought to be avoided by the application of a safety factor. The scientific facts upon which the Safety Model is implemented are those obtained in laboratory studies.

The *Medical Model* is ordinarily used to decide whether a particular drug or device is safe for use in patients, and whether it is efficacious for the particular purpose suggested by the sponsoring company. The drug or device is tested in laboratory experiments to ascertain whether it has the power to affect the system of the body it would ultimately be used to treat in patients. For example, if the drug is intended to affect the musculoskeletal, cardiovascular, immune, or nervous systems, experimental demonstrations are made of the power of the drug or device to produce effects in the corresponding system in animals. A small but coordinated group of laboratory studies is performed. Additional studies are done to determine whether the drug or device was likely to produce *side-effects.* Such experiments are done at doses or exposure that are higher than those contemplated for human use. By definition, a side-effect is any effect produced by the drug or device other than the effect it is intended to produce. There are no good side-effects; a side-effect is presumed to create risk.

If warranted by the laboratory studies, further studies on patients are conducted to assess safety and efficacy. The clinical studies aimed at rationalizing a drug or device with regard to these endpoints typically employ 10-1000 patients, thereby producing the scientific facts upon which regulatory authorities base judgments regarding safety and efficacy in humans. The applicable standard of evidence is one of preponderance; it is applied to the overall results of the clinical study, not to the results in individual patients. For example, it is always the case that some patients treated with a particular drug or device do not receive a cure, and it is frequently the case that some patients are worse off after having been treated.

If the benefits of the drug seem to the responsible authority to outweigh the side-effects, the drug may be licensed for sale. Thereafter, individual physicians and patients make a judgment regarding use of the drug based on a second risk-benefit weighing.

The Medical Model employs scientific facts produced in laboratory studies and in clinical studies (which are a refined version of the epidemiological study discussed earlier).

The *Fairness Model* is used to evaluate environmental exposures experienced by the general public under conditions where the public has not made a conscious decision to be exposed to the agent, and might be willing to do so for the benefit of another party, providing that such acquiescence did not entail a health risk. A typical application of the model is zoning cases where uses on adjacent property may create health risks for nearby residents. I have observed application of the model in cases involving the siting of cellular telephone towers and television antennas.

The issue considered when the Fairness Model is applied is whether situations roughly similar to the one under consideration have resulted in harm to other people. The evidence considered is usually that provided by pertinent epidemiological studies, which are often sufficient to warrant relying on a general dispositive principle such as the choice to err on the side of safety.

The *Toxicological Model* is typically used by industry trade groups, unions, and governmental agencies that regulate workplace exposures to potential toxic agents. Individuals exposed in the workplace are typically healthy adults, and restrictions on exposure levels characteristically reduce industry efficiency. Consequently, the basic

philosophy is that clear and definite evidence of actual harm is needed to warrant the imposition of exposure limits.

In the following sections I will evaluate the available scientific facts dealing with the biological effects of EMFs with relation to each of the four models, as applied to the pattern of EMF exposure that will occur on the Benson property. Before doing so, however, I will present in the next section a brief summary of some pertinent scientific investigations that have been carried out by my colleagues and me over the past 5 decades so that the court will have perspective on two important points that were not treated previously in detail: (1)!the long incubation period of the basic issue involving health risks from powerlines; (2)!a specific example of how scientific facts such as "exposure to powerline EMFs is a health risk" are underdetermined by observation and theory, and depend in part on choices of values and policy.

CONTEXTUAL MATTERS

I think it is important for the court to understand the scientific context within which scientific evidence pertinent to the health-risk issue on the Benson property has arisen. I have already described some contextual issues that I believe impact directly on the scientific merit of EMF biological studies. In this section I will describe several lines of research dealing with the effects of EMFs performed in my laboratory so the court can appreciate the long incubation period that has occurred in the process by which the implications of laboratory and epidemiological research dealing with EMFs has come to be appreciated and understood.

In the late 1960s I performed experiments that showed human bone exhibited the special property of being able to generate an electrical signal when it is subjected to normal mechanical forces, such as those generated during walking ("piezoelectricity"). This work showed that bone, like nerves and muscles is essentially an electrical tissue, able to generate electrical signals in its normal state in the body. Subsequent work from my laboratory and many other laboratories established that almost all tissues in the body exhibit the property of piezoelectricity, and can therefore be considered to be electrical in nature. Moreover, many studies in which EMFs were applied to bone demonstrated that they had the power to stimulate it to grow, and now the application of EMFs for certain bone diseases is a standard orthopaedic practice, worldwide. In view of the fundamental electrical nature of living organisms, including human beings and the ability of electrical energy to bring about therapeutic results under controlled circumstances, it should not be surprising that the application of electromagnetic fields

could have the potential of interfering with natural ongoing electrical processes when applied in an uncontrolled fashion as along a powerline right-of-way, leading to disease.

In the 1970s my colleagues and I reported that rats exposed to powerline electric fields for 30 days exhibited physiological changes normally exhibited in subjects undergoing stress (Appendix 2, Report No. 3). Subsequently, many reports appeared in the peer-reviewed scientific literature describing stress reactions in laboratory animals and human subjects exposed to EMFs similar to those produced by powerlines. It is a well accepted physiological principle that stressed subjects exhibit higher disease levels than comparable subjects not undergoing stress.

In 1981 my colleagues and I reported the results of an epidemiological study in which we found an association between powerline magnetic fields and the occurrence of suicide (Appendix 2, Report No. 4). Many subsequent studies indicated that EMFs could produce psychological changes in exposed subjects less severe than suicide, thereby suggesting that depression, reduced performance, and other similar conditions could be triggered by exposure to EMFs.

In the 1990s I reported that mice exposed to powerline electric fields exhibited altered growth rates, confirming several other studies that I had published 10-15 years earlier (Appendix 2, Report No. 5). Subsequently, many other investigators reported that power-frequency electric and magnetic fields could affect the growth rate of animals.

The obvious implications of these peer-reviewed publications with regard to risks for similarly exposed human subjects have been opposed and denied by the power

industry and their experts. The process by which this occurred illuminates an important aspect of scientific reasoning that should be recognized.

Following publication of my reports that power-frequency electric fields altered the growth rate in mice, power industry scientists working at the Battelle Institute in
Richland, Washington were given a large contract to study the same subject. When the investigators performed the study they found that the mice exposed to the electric field was significantly smaller than the controls. The effect was statistically significant, meaning that the observed average difference in weight could not realistically be attributed to chance (95% certain). The investigators found similar decreases in average weight in both the males and females. The investigators replicated the entire experiment (which took more than 9 months). In their second experiment, they found that both the males and females were significantly heavier than the controls, and that the results were 95% certain.

The investigators were faced with an interpretive problem regarding the implications of the data regarding the effect of powerline electric fields on mice. There are no iron-clad scientific rules that require a particular choice of how the results of the two studies ought to be construed together. My view of the proper construction of the results, which I expressed 20 years ago after I first learned of the results of the experiments and which I still think is the proper interpretation, is that the results indicated that powerline electric fields can affect processes in the animal body that govern its growth, and that the direction of the effect, whether to increase or decrease growth depends on some factors that were not controlled in the two experiments and

that differed between them. The result is that the evidence establishes the fact of an effect due to the powerline electric field but the inability to predict the direction of the effect, like the inability to predict weather. The response of the study investigators, however, was to average the results of the two independent experiments and conclude that the powerline electric field had no effect whatever on the growth of the mice, and hence the studies provided no support for the proposition that powerline electric fields might be a health risk.

It is clear that the values and policies that were incorporated into the judgment were those favored by the power industry. This example shows better than most how policy and values can determine what some regard as scientific facts.

In the late 1990s my colleagues and I performed a series of studies that showed powerline magnetic fields could alter the immune system in mice (Appendix 2, Report No. 6). Many other reports, almost all originating outside the orbit of the power industry, have similarly shown that animals and human subjects exposed to EMFs can exhibit altered immune systems. In 2002 my colleagues and I published a report showing that powerline magnetic fields could alter the brain electrical activity of rabbits (Appendix 2, Report No. 7). This is the latest report in a series of approximately 6 publications showing that magnetic fields can alter brain electrical activity in animals and human subjects. Many other investigators have demonstrated a similar effect.

Thus, the immune system and the central nervous system, the two main sensory and regulatory systems of the body, can be directly altered by the imposition of powerline magnetic fields. It should not be surprising, therefore, that uncontrolled, long-

term exposure to such fields such as normally occurs along a powerline right-of-way will be inimical to health and cause disease.

SAFETY MODEL

On the basis of the worst-case analysis of the strength of the magnetic field produced on the Benson property by the Maudsland-Molendinar powerline, the Bensons will be exposed to average magnetic fields of 6.3-7.1!mG in their home and 12.4- 18.7!mG in their backyard. On the basis of the worst-case analysis of the strength of the electric field produced on the Benson property by the Maudsland-Molendinar powerline, the Bensons will be exposed to average electric fields of 93.1-102.6!volts/meter around their home and 170.2 264.1!volts/meter in their backyard. The magnetic and electric fields will each be present more or less continuously, thereby resulting in chronic exposure to persons living in the home.

Electric and magnetic fields produced by the electrical power system are common in the environment and result in almost universal exposure of the population. However, the amount of exposure ordinarily experienced by persons who do not live beside powerlines or use electric blankets is far less than will occur on the Benson property. Typically, the average magnetic-field exposure of the population is about 0.5!mG, and is almost always below 0.1!mG for ther great majority of the population.

The characteristic exposure levels for electric fields have never been measured, but are probably 2-5!Volts/meter. It is clear, therefore, that the exposure levels at the Benson property caused by the Maudsland-Molendinar powerline are far above the levels that would otherwise occur. In other words, the Bensons will experience essentially the same EMF levels as those experienced by others in the population and,

in addition, will experience additional exposure up to 100 times greater than normally experienced.
The estimates given above underestimate the actual exposure that will occur on the Benson property under worst-case conditions because the calculated values apply only to the strength of the fields at ground level. The strength of the fields at chest level of subjects on the first floor will be about 5% higher; the values for individuals on the second floor will be still higher by about 5%.

The doses of electric and magnetic fields produced by exposure to fields derived from powerlines are qualitatively and quantitatively different than the exposures produced by exposure to fields from household devices. For example, one might measure a field of 1!mG near a vacuum cleaner. However, the field will only reach that level at one point near the body, and will be anywhere from 10 to 100 times lower at other locations on the body. Thus, the average field, averaged over the body surface area, produced by a typical household device will be a fraction of the value obtained during a spot measurement. In addition, as I mentioned above, the average magnetic field exposure is approximately 0.5!mG, averaged over a 24-hour day. The average exposure, averaged over time, from a particular household device is relatively negligible
(it is the sum total of such exposures that produces the average exposure of 0.5!mG).

Under the laws of physics, it can be confidently predicted that both the magnetic and electric fields will produce specific kinds of physical changes in the cells in their bodies. In response to the magnetic field, each atom in each cell in each tissue will undergo some form of motion, either vibration, rotation, linear movement, or some

combination of these motions. The electric field will produce similar qualitative effects relatively more concentrated in the peripheral organs (skin, cerebral cortex, for example). The existence of these physical motions is indisputable.

The question considered in the context of the Safety model is whether the physical effects that occur in response to magnetic and electric fields having the magnitudes listed above are likely to produce or lead to biological effects. The question is resolved on the basis of an evaluation of the pertinent peer-reviewed laboratory studies dealing with exposure of laboratory animals and human beings to EMFs comparable to those produced by the Maudsland-Molendinar powerline, together with the application of a safety factor of 100 to allow for the fact that the relatively short exposure periods typically studied in the laboratory and the relatively few number of laboratory studies performed might otherwise lead to a gross underestimation of the actual risk.

A cross-section of the applicable peer-reviewed scientific publications is presented in References, and some of those publications are described with more particularity in Table 1. For reasons given above laboratory studies that were controlled by the power industry (mostly the Electric Power Research Institute, other American industry trade associations, and individual power companies in the United States, and to a lesser extent the national power industries in England, Italy, and Germany) were generally not considered because the work is riddled with the fact and appearance of impropriety. However, for reasons discussed below, the conclusions reached would be the same even if the tainted work were included in the analysis.

Table 1. Biological Effects of Electromagnetic Fields in Laboratory Studies

Investigator	Institution	Animal Studied	Eeffect Observed	Field Strength
Hansson	Univ. of Goteborg	Rabbits	Brain tissue	14 kV/m
Sazanova	Leningrad Univ.	Rabbits	Muscle strength	30 kV/m
Friedman	VA Hosp.-Syracuse	Humans	Stress	3 G
Gann	Johns Hopkins	Dogs	Heart rate	15 kV/m
Marino	VA Hosp.	Rats	Fracture healing	5 kV/m
Marino	LSU-Shreveport	Humans	Brain electrical activity	780 mG
Beischer	Naval Aerospace Lab	Humans	Serum fats	1 G
Gibson	Naval Aerospace Lab	Humans	Reduced performance	1 G
McElhaney	W. Virginia Univ.	Rats	Bone tumors	7 kV/m
Giarola	Texas A&M Univ.	Chicks	Depressed growth	3.5 kV/m
Krueger	Texas A&M Univ.	Chickens	Egg production	1.6 kV/m
Lott	North Texas StateUniv.	Rats	EEG	40 kV/m
Bawin	UCLA	Brain tissue	Calcium metabolism	10 V/m
Delgado	Ramon y Cajal (Spain)	Chicks	Abnormalities	2- 120 mG
Hamer	UCLA	Humans	Reaction time	4 V/m
Gavalas	UCLA	Monkeys	Behavior	3.5 V/m
Wever	Max Planck Inst.	Humans	Circadian rhythm	2.5 V/m
Noval	Temple Univ.	Rats	Growth	0.5 V/m
Southern	Northern Illinois Univ.	Birds	Behavior	0.2 V/m
Graue	Bowling Green State	Birds	Behavior	0.07 V/m
Larkin	Rockefeller Univ.	Birds	Behavior	0.07 V/m
Williams	Swarthmore College	Birds	Behavior	0.07 V/m
McCleave	Univ. of Maine	Fish	Behavior	0.07 V/m
Blackman	US EPA	Nerve cells	Nerve cell growth	100 mG

Crasson	Univ. of Liege	Humans	Brain activity	1 G
Potschka	Hanove	Rat	Altered brain activity	1 G
Preece	Bristol, UK	Humans	Deterioration in attention and memory performance	6 G
Bonhomme-Faivre	France	Mice	Altered hematological and immune systems	50 mG
Beale	Univ. of Aukland	Humans	Increased psychiatric symptoms	0.5-10mG
De Jager	Univ. Orange Free State	Mice	Higher incidence Of death	10 kV/m
Mueller	Zurich	Humans	Electrical hyper-sensitivity in some subjects	100 V/m/60mG
Rajkovic	Novi Sad	Rats	Altered thyroid Glands	0.5-5 G
van den Heuvel	Belgium	Mice	Altered bone marrow cells	0.8 G
Al-Akhras	Jordan	Rats	Decreased fertility of males and females	250 mG
Graham	Kansas City	Humans	Altered sleep quality	283 mG
Akerstedt	Karolinka Inst.	Humans	Altered sleep patterns	10 mG
DiCarlo	Catholic Univ.	Chick Embryos	Altered survival rates	60-100mG
Campbell-Beachler	Loma Linda	Tumor cells	Altered gene Expression	0.1-1 G
Kavaliers	Univ. of Western Ontario	Mice	Altered reaction to drugs	1 G
Burchard	McGill Univ.	Cows	Altered brain Chemistry	10 kV/m/300 mG
Jenrow	Henry Ford Hosp.	Rat brain	Altered Electrical activity	289 mG
Harland	Univ. of California	Human breast Cancer cells	Altered hormone Activity	12 mG

Bawin	Loma Linda	Rat brain	Altered electrical Activity	560 mG
Ossenkopp	Univ. of Western Ontario		Rats Altered epileptic Seizures	0-1.85 G
Marino	LSU-Shreveport	Rabbits	Altered immune System	1 G
Liboff	Oakland University	Rats	Behavior	270 mG

Perusal of the studies listed in Table 1 reveals that there are numerous instances in which magnetic and electric fields in the Benson home and backyard will be at levels shown to produce biological effects in animals, or at levels that are within a factor of 100 of the levels that produce biological effects in laboratory studies. It follows, therefore, that the conditions created by the Maudsland-Molendinar powerline will create a health risk on the Benson property .

Assuming that the taint of the industry studies were overlooked, my conclusion would be the same for the following reason. The best that could be said for the industry studies is that they were truly negative, that is, they were studies in which exposed animal and human subjects did not exhibit biological effects when exposed to powerline EMFs. But not finding something does not yield a scientific fact, at least in the same sense of the meaning of fact when it is used to describe the result of a positive experiment. The result of a positive experiment indicates or describes objective reality
and therefore has ontological existence. The result of a negative experiment indicate only that no evidence was found in favor of the ontological existence of some fact. The result does not mean, and under ordinary circumstances cannot validly be interpreted to

mean, that the fact searched for does not exist. The simple truth is that the investigator may have simply looked in the wrong place.

In the Safety Model the guiding philosophy is one of erring on the side of caution because the populations that will be exposed include not only healthy young adults, but the old and the young, which are populations that are relatively more susceptible to factors that promote disease. Additionally, it should be remembered that the risks sought to be protected against are experienced involuntarily in the sense that the persons who experience the risks never specifically agree to accept them. which is entirely possible as, for example, persons who are apprised of the honest research regarding EMFs and still choose to live beside a powerline for reasons that seem best to them.

The Safety Model best fits the situation on the Benson property, judging by the parallel between the situation there and the situations for which the model has been used previously. However, other models are potentially applicable, and the results reached employing them are described in the following three sections.

THE FAIRNESS MODEL

The principle behind the Fairness Model is very old, at least within the tradition of the English common law. A famous American judge named Cardozo gave what is perhaps the best explanation of this principle in a case that he decided in 1925. A real estate broker had been hired to sell a building, and through a dummy corporation he made an offer which he knew his client would accept. The broker then resold the property a few weeks later at a handsome profit. In his decision, Cardozo pointed to the obvious conflict-of-interest: a broker's duty is to get the highest price, but a buyer's goal is the opposite. The broker claimed that he had revealed enough information when he told the client that the corporation was also a client. Not good enough, said Cardozo and he laid down the rule regarding disclosure that applies to someone who has conflicted interests: "If dual interests are to be served, the disclosure, to be effective,

The model fits a situation where there is an inequality between the two parties regarding the quality and extent of knowledge regarding a matter that affects both parties. For example, one party may be deeply knowledgeable concerning biological and engineering aspects of designing, building, and operating high-voltage powerlines and the other party who was affected in some way by the activity has little or no such knowledge. In addition to the difference in knowledge between the parties, there also needs to be some relationship between the parties such that one party has a special obligation to safeguard the interests of the other. The model does not fit a situation involving bargaining between equals, but rather a case where a knowledgeable and

more powerful party is contemplating a course of action that serves its interests that potentially impacts the other party, to whom some form of duty is owed.

In cases where the model is applicable, almost all of the benefit flows to the dominant party and almost all of the risk flows to the subservient party, consequently evidence whose fair import is that the subservient party might suffer can be sufficient to propose safeguards that would prevent creation of the putative risk. One would not normally expect any technical evidence considered that involves any form of judgment or opinion be provided by one of the parties for the obvious reason that there is a possibility that the evidence would be self-serving.

What is the bare truth regarding what is known about the health effects of living within the electromagnetic field from powerlines? Various investigators have attempted to answer this question by directly examining disease levels among people who lived near powerlines. A representative sample of these studies is presented in Table 2, which shows that increased rates of many horrible diseases were elevated.

Considered with respect to some platonic ideal of Truth the studies suffer from many shortcomings. We do not know precisely what EMF strengths to which they were exposed nor for exactly how long. We cannot be certain that it was the EMF from the powerlines rather than some other factor that was responsible for the increased disease levels. We do not know by what mechanisms the EMFs produced the disease, and we do not understand the role of confounding factors, smoking for example. In addition, there was a relatively equal number of studies, not listed in Table 2, that did not find elevated levels of disease. Taking all these limitations into consideration, and perhaps

other limitations that I didn't mention which might be important, it is still abundantly clear that numerous epidemiological studies have drawn an association between living near powerlines and a risk for cancer. In order to invoke the principle of erring on the side of caution it seems reasonable to expect that the number of epidemiological studies that provoke the use of the principle, and their quality be above some appropriate threshold. In my view, the studies listed in Table 2 are above the requisite threshold for the following reason: I can find no other situation or circumstance where an equal number of studies has been found insufficient to warrant taking precautions to guard against exposure. For this reason, in this case, a fair thing to do might be to put the powerline underground or to move it away from the Benson residence. In view of the number of published studies, the alternative, which would be to build the line as proposed, with Powerlink given a kind of parental responsibility to monitor future scientific developments and advise the Bensons if these developments indicated that the powerline was indeed a health risk seems unfair.

TABLE 2. Disease associated with residential exposure to powerline electromagnetic fields.

Investigator	Country	Disease	% Increase Due to EMF Exposure
Wertheimer	Colorado, USA	All cancer	209%
		Leukemias	198%
		Brain	146%
Tomenius	Sweden	Leukemia	120%
		Brain	420%
McDowall	England	Lung cancer	115%
Savitz	Colorado, USA	All cancer(2mg)	53%
		Brain cancer (2mG)	100%
Lin	Taiwan	Lymphomas	100%
Youngston	England	Myeloid leukemia	188%
Olsen	Denmark	Lymphoma	400%
Feychting	Sweden	Leukemia (3mG)	280%
Fajardo-Gutierrez	Mexico	Leukemia	163%
Juutilainen	Finland	Spontaneous abortion	444%
Feychting	Sweden	Lymphoma	130%

TOXICOLOGICAL MODEL

The model is typically applied by industry trade groups, unions, and governmental agencies that regulate workplace exposures to potential toxic agents. Individuals exposed in the workplace are typically healthy adults, and restrictions on exposure levels characteristically reduce industry efficiency. Consequently, the basic philosophy is that clear and definite evidence of actual harm is needed to warrant the imposition of exposure limits. Consequently, in most countries, the exposure limits for EMFs in the occupational setting are invariably far higher than those in any other setting (if they exist). For EMFs, for example, the exposure levels are usually set on the basis of gross or obvious phenomena, such as heating, burning, electrical shock, or other physical sensation. Many studies of exposed worker populations have reported an increased level of disease (see Table 3). However, insofar as I am aware, no disease has been recognized by the groups mentioned above as clearly and convincingly associated with the presence of EMFs (in their judgment) as to warrant exposure limits lower than those that guard against acute effects.

If the toxicological model is applied to the available scientific evidence regarding
the biological effects of EMFs comparable to those on the Benson property, then the available evidence would probably not indicate that those levels will be a health hazard.

TABLE 3. Disease associated with occupational exposure to electromagnetic fields.

Investigator	Country	Occupation	Disease	%Increase Due to EMF Exposure
Milham	Washington, USA	Aluminum workers	Brain Cancer	53%
Demmers	USA	Telephone linemen	Breast cancer	500%
Hemminki	Finland	Metal industry	Spontaneous abortion	130%
Milham	Washington,USA	All occupations	Leukemia	37%
Wright	California, USA	All workers	Leukemia	29%
Coleman	United Kingdom	Electrical workers	Leukemia	131%
Calle	California, USA	Electrical occupations	Leukemia	157%
Gilman	USA	Coal miners	Leukemia	153%
Lin	Maryland, USA	Electrical occupations	Brain cancer	178%
Milham	Washington,USA	Electrical occupations	Leukemia	91%
Pearce	New Zealand	Electrical workers	Chronic leukemia	112%
Spitz	Texas, USA	Electrical workers	Brain cancer	113%
Vågerö	Sweden	Electrical workers	Melanoma	150%
Flodin	Sweden	Electrical workers	Leukemia	280%
Thomas	New Jersey,USA	Electrical workers	Brain cancer	290%
Cartwright	United Kingdom	Electrical workers	Leukemia	150%
DeGuire	Canada	Telecommunication workers	Melanoma	170%

Johnson	Texas, USA	Electrical manufacturing	Nervous system tumor	252%
Pearce	New Zealand	Electrical workers	Leukemia	62%
Reif	New Zealand	Electrical engineers	Brain cancer	374%
Bastuji-Garin	France	All occupations	Leukemia	220%
Juutilainen	Sweden	Occupational exposure	Leukemia	42%
Loomis	USA	Electrical engineers	Brain cancer	170%
Demers	USA	Plant operators	Brain cancer	350%
Richardson	France	All occupastions with exposure	Leukemia	290%
Floderus	Sweden	Linemen and plant Operators	Leukemia	200%
Persson	Sweden	Electrical occupations	Lymphoma	130%
Loomis	USA	Electrical workers	Breast cancer	17%
Thériault	France, Canada	Electrical workers	Leukemia	141%