A White Paper On Electric And Magnetic Field (EMF) Policy And Mitigation Options

Prepared By

The Minnesota State Interagency Working Group On EMF Issues

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EXECUTIVE SUMMARY

Over the last two decades concern about the health effects of electric and magnetic fields (EMF) has increased. Early scientific studies reported a weak association between increased rates of cancer and closeness to certain kinds of power lines that can cause strong electric and magnetic fields. As more electric facilities are built to meet growing demands for electricity, policy makers will increasingly be faced with questions regarding the potential health impacts of EMF. This report is the result of an interagency work group that was formed to examine these issues and provide useful, science-based information to policy makers in Minnesota.

Electric and magnetic fields are a basic force of nature generated by electricity from both natural and human sources. Exposure to EMF comes from high voltage transmission lines and distribution lines, wiring in buildings, and electric appliances. Electric fields are easily shielded by common objects such as trees, fences, and walls. Magnetic fields are difficult to shield; this is why magnetic fields produced by power lines can extend into people's homes.

Transmission and distribution lines are part of the complete electric power system. Transmission lines carry between 69 and 500 kilovolts (kV) of electricity and transport it from generation sources to regions of the state needing electricity. Primary distribution lines generally carry less than 69 kV of electricity and bring it from transmission lines to homes, offices, and other sites where there are end users of electricity.

Based on forecasts of future electrical use, Minnesota has now reached the point at which new generation and transmission capacity is needed. Over the ten years from 1990 to 2000, total annual electric consumption in the State grew by 27 percent; summer peak demand is predicted to grow by 16 percent over the next ten years. Several transmission expansion projects are planned over the next ten years to meet this demand. These projects will need to be reviewed and approved by the Public Utilities Commission and the Environmental Quality Board.

Research on the health effects of EMF has been carried out since the 1970s. Epidemiological studies have mixed results – some have shown no statistically significant association between exposure to EMF and health effects, and some have shown a weak association. More recently, laboratory studies have failed to show such an association, or to establish a biological mechanism for how magnetic fields may cause cancer. A number of scientific panels convened by national and international health agencies and the U.S. Congress have reviewed the research carried out to date. Most concluded that there is insufficient evidence to prove an association between EMF and health effects; however, many of them also concluded that there is insufficient evidence to prove that EMF exposure is safe.

In deciding whether or how much to regulate EMF, decision-makers have several possible options. Each approach has advantages and disadvantages. At one extreme, regulators can require virtual certainty of harm before they address it. At the other extreme, proposers of a project would need to demonstrate its safety before regulators would allow them to proceed. Several options along this continuum are presented below for regulators to consider when routing power lines.

Several EMF exposure mitigation options are available. Mitigation options for transmission lines include increasing distance to the EMF source, phase cancellation by changing the proximity of the conductors, shielding the EMF source, and reducing voltage or current levels on the lines. Principles for decreasing EMF from primary distribution lines are similar and include increasing the right-of-way around distribution lines, phase cancellation, and burying the lines. There are also several options for mitigating EMF exposure in the home, including increasing distance to operating appliances and properly following electrical codes for wiring the home.

The Minnesota Department of Health (MDH) concludes that the current body of evidence is insufficient to establish a cause and effect relationship between EMF and adverse health effects. However, as with many other environmental health issues, the possibility of a health risk from EMF cannot be dismissed. Construction of new generation and transmission facilities to meet increasing electrical needs in the State is likely to increase public exposure to EMF and public concern regarding potential adverse health effects.

Given the questions and controversy surrounding this issue, several Minnesota agencies that regularly deal with electric generation and transmission formed an Interagency Work Group to provide information and options to policy makers. Work Group members included representatives from the Department of Commerce, the Department of Health, the Pollution Control Agency, the Public Utilities Commission, and the Environmental Quality Board. Based on its review, the Work Group believes the most appropriate public health policy is to take a prudent avoidance approach to regulating EMF. Based on this approach, policy recommendations of the Work Group include:

- Apply low-cost EMF mitigation options in electric infrastructure construction projects;
- Encourage conservation;
- Encourage distributed generation;
- Continue to monitor EMF research;
- Encourage utilities to work with customers on household EMF issues; and
- Provide public education on EMF issues.

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INTRODUCTION

Over the last two decades concern about the health effects of electric and magnetic fields has increased. Early scientific studies reported a weak association between increased rates of cancer and closeness to certain kinds of power lines that can cause strong electric and magnetic fields (EMF). However, other studies conducted since then refute those results. Given this uncertainty, there has been considerable public debate about the potential health risks from exposures to EMF. Questions include: Does EMF cause cancer or any other adverse health effects? Is there a safe level of exposure for EMF?

Additionally, there has been interest in mitigating exposures to EMF. Questions asked in this regard include: What are the ways that exposures to EMF can be reduced? What are the costs? What are the current policies and regulations in Minnesota and other states?

State and local policy makers will increasingly be faced with questions regarding the potential impact of EMF. Consumption of electricity has been growing in Minnesota in recent years and is projected to grow more in the future. Given this increased demand for electricity, it is expected that more electric facilities will need to be built, thus increasing potential EMF exposure.

In an attempt to provide state and local decision-makers with guidance on EMF research and public policy, an interagency work group was established.[1] The group focused on evaluating the current state of EMF health effects research, reviewing policies and mitigation strategies from other states, and providing a framework for decision-making on various regulatory options. This report is the result of that effort.

Chapter 1 of this report explains basic concepts related to EMF. Chapter 2 describes the electrical infrastructure in Minnesota, the increasing demand for electricity in the State, and projected new construction of electric facilities. Chapter 3 discusses the current state of the health effects research on EMF. Chapter 4 outlines various regulatory approaches in considering EMF issues, while Chapter 5 describes methods for reducing EMF exposure. Finally, Chapter 6 contains conclusions and policy recommendations developed by the work group. A survey of other states' activities and policies related to EMF regulation is included in the Appendix.

The scope of this report is limited to extremely low frequency fields from electrical sources such as power lines and substations, household wiring, and appliances. It does not address research or policies related to radio frequency fields such as AM/FM radio, television, cellular phones, or any other frequencies. This report also does not address issues related to occupational EMF exposures or stray voltage.

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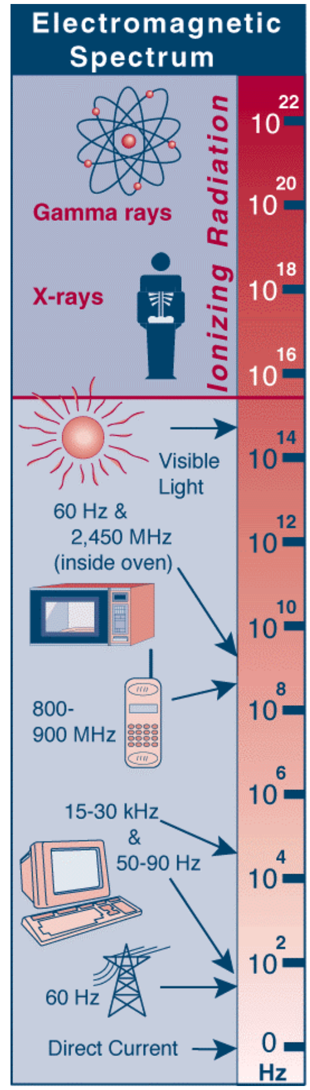
[1] Work Group representatives included staff from the Minnesota Department of Health, Department of Commerce, Public Utilities Commission, Pollution Control Agency, and Environmental Quality Board.

CHAPTER 1: A PRIMER ON ELECTRIC AND MAGNETIC FIELDS

Electric and magnetic fields (EMFs) are a basic force of nature (like gravity) generated by electricity. EMFs are found in nature, where they are created by such things as lightning and static electricity. Man-made fields are found wherever people use electricity. Electric fields arise from voltage on conductors. They are measured in volts/meter or kilovolts/meter and are easily shielded by common objects such as trees, fences, and walls. Magnetic fields arise from the current flowing through the conductors. They are measured in units of milligauss (mG) and are very difficult to shield. This is why the magnetic fields produced by power lines can extend into people's homes



Like sound, electric and magnetic fields are made of a mixture of components and so can be described in many different ways. The fields can be strong or weak, have a high or low frequency, have sudden increases in strength (transients) or a constant strength, and consist of one pure frequency or several (called harmonics). Power lines and wiring in buildings and appliances generate 50 and 60 Hertz fields, sometimes referred to as "power frequency" fields. (Frequency is measured in cycles/second). Power frequency fields are low frequency fields and have low energy levels.

Sources of EMF Exposure

We are exposed to EMF from many sources, including high voltage transmission lines (usually on metal towers) carrying electricity from generating plants to communities, and distribution lines (usually on wooden poles) that bring electricity to our homes, schools and workplaces. We are also exposed to magnetic fields from wiring in buildings and from all our electric appliances like TV sets, radios, hair dryers, electric blankets and electric tools.

Average Levels of EMF Exposure

The strength of magnetic fields varies depending on many different factors, including the magnitude of the current and the proximity to an EMF source. Because magnetic fields decrease with distance from the source, the magnitude of the magnetic field is higher in homes near a power line than those further away. Similarly, levels near appliances or interior electrical wiring may be higher than an average mid-room reading.

The electric field under a high voltage transmission line is usually not more than 10 kV/meter when measured 1 meter above ground. (In Minnesota the lines subject to permits from the

Environmental Quality Board have been restricted to a maximum of 8 kV/m). Because most materials shield the electric field the typical electric field in a house does not exceed 100 V/m.

In a study conducted by the Electrical Power Research Institute, spot measurements in 992 homes throughout the U.S. showed that half (50%) of them had magnetic field measurements of 0.6 mG or less, when the average of measurements from all the rooms in the home was calculated. These measurements primarily reflect the fields from internal household wiring, electrical grounding sources, and power lines. Exposures in occupational settings (e.g., working on a computer or operating a machine/tool) are typically much higher than residential settings.

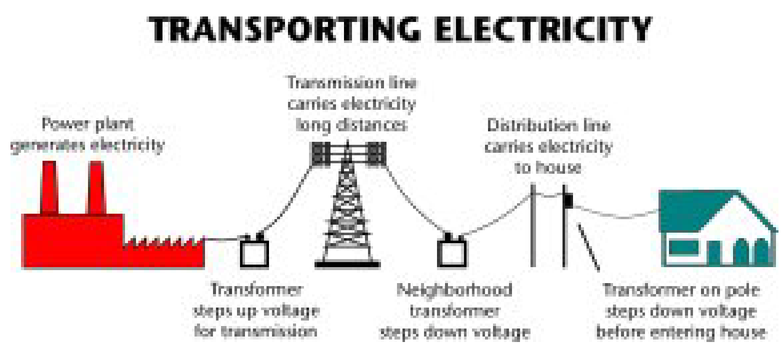
In 1998 a nationwide random survey of 1000 individuals was conducted to measure 24-hour time-weighted average exposures to magnetic fields (Zaffanella & Kalton, 1998). The geometric mean for this survey was 0.9 mG. Approximately 15% of the population was estimated to have exposures exceeding 2 mG; 2.4% had exposures exceeding 5 mG, and 0.4% had exposures exceeding 10 mG. The last value indicates that about 1 million people in the U.S. have an average 24-hour exposure greater than 10 mG. Peak exposures at a single point in time are often considerably higher due to peoples' exposures to appliances, wiring, and other sources. About 0.5% of the population had an estimated maximum (peak) exposure to magnetic fields of 1000 mG.

Overall, commercial and residential power distribution systems can be a more significant source of magnetic field exposure than transmission lines, but they are usually not a very significant source of large electric fields.

CHAPTER 2: MINNESOTA'S ELECTRIC SYSTEM INFRASTRUCTURE

How the Electrical System Works

The complete electric power system is a complex mix of generation, transmission lines, and distribution lines, interspersed with substations and transformers that adjust the voltages between the various lines and the end user. The transmission and distribution lines are also referred to as conductors because they conduct the electricity along the lines to the end user. As commonly used in Minnesota, transmission lines are lines that carry between 69 and 500 kilovolts (kV) of electricity and transport it from generation sources to regions of the state needing electricity. Primary distribution lines bring electricity to homes, schools, offices, and other sites where there are end users of the electricity and generally carry less than 69 kV of electricity. The actual voltage depends on the need; common voltages for primary distribution are 4 kV, 12.5 kV, and 24.9 kV. Voltage on primary distribution lines is stepped down by either a pole-mounted transformer for overhead primary lines or by pad-mounted transformers for underground primary lines. The electricity is then delivered to the end user via secondary distribution lines.



Building the Electrical Infrastructure

Construction of Generation Facilities

Electric generation facilities have generally been constructed to meet forecasted demand for electricity. Minnesota utilities constructed a great deal of generation capacity in the 1960's and early 1970's, with the expectation that electricity use was going to grow significantly during the following decades. A combination of factors, including the 1973 oil embargo, led to a significant slowing in the growth of electricity use, which provided Minnesota with excess generation and major transmission line capacity for about 20 years. The last major baseload generation facility constructed in Minnesota was the Sherco 3 unit in 1987; the last major transmission line was constructed in 1981.[2]

[2] For a complete list of recent electric facilities, please see the Department of Commerce's State Energy Plan, which can be found at http://www.commerce.state.mn.us/pages/Energy/MainEnergyPolicy.htm

Construction of Transmission Lines

The construction of major transmission lines in the State has generally followed the construction of major electric generation facilities. In addition, land-use patterns and the sites chosen for new generation have affected the configuration and need for transmission lines. For example, generation may be located away from populated areas for environmental reasons, or to have access to railroad locations, water, or other facilities needed to generate electricity. However, the farther away generation facilities are located from customers, the more transmission facilities are needed to deliver electricity to consumers. Moreover, location of businesses and homes in more rural areas can also increase the need for transmission facilities.

Construction of Distribution Lines

Although the construction of major transmission lines has been slow, construction of distribution lines and associated facilities has continued to grow. Construction of distribution facilities is tightly coincident with construction of new housing and commercial development, which have grown significantly in several parts of the state. Upgrades of older distribution facilities also occur as a response to changing customer uses, such as larger appliances and computers, that place additional demands on the electric system.

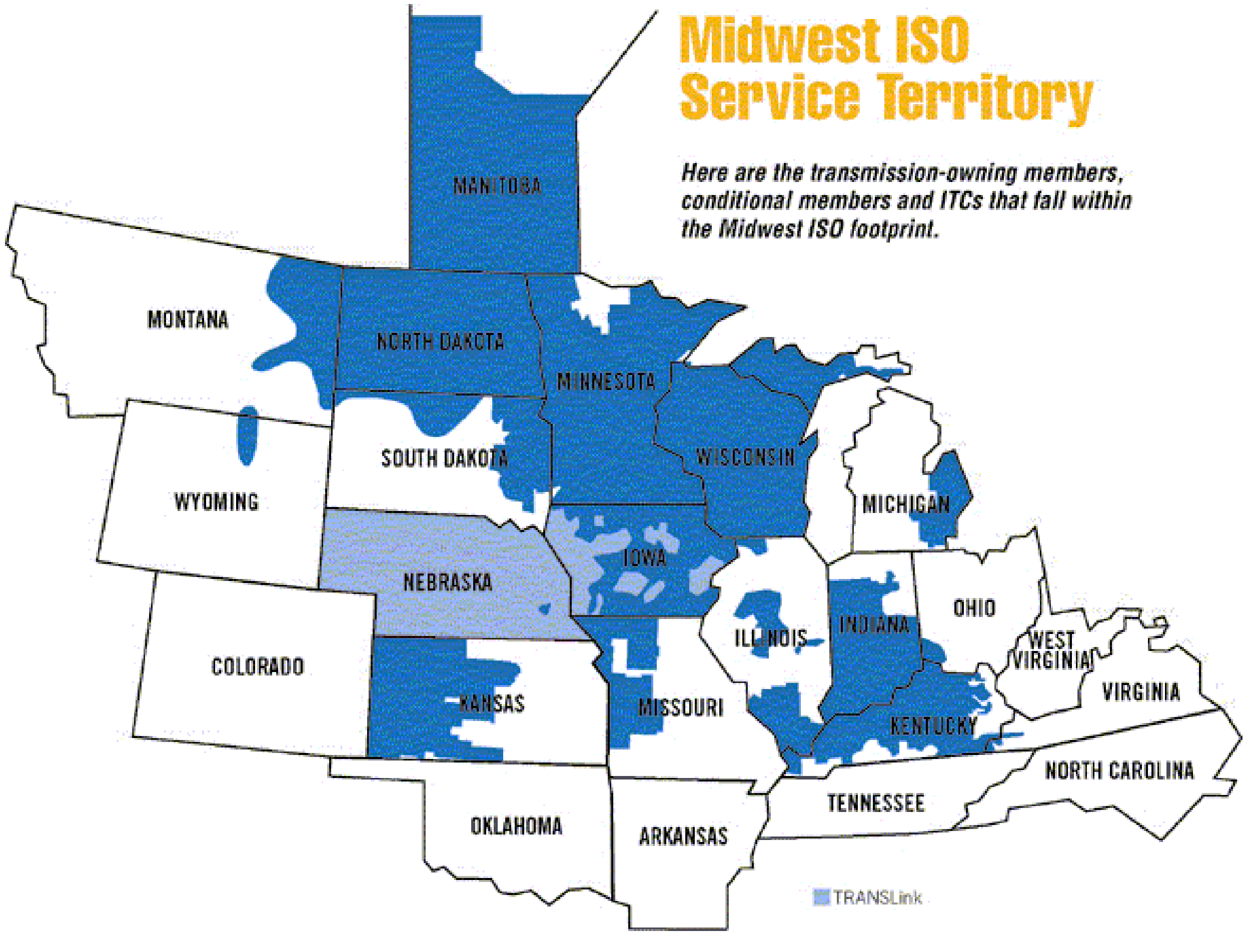
Planning and Approving New Infrastructure

The production of electricity has generally been subject to a public review of the need for generation and transmission facilities. Since production is controlled by a variety of private entities, the public and private sectors interact to determine the need for new electric generation and transmission systems.

The North American Electric Reliability Council (NERC) is the electric reliability organization for all of North America. Its members are its subregional reliability organizations. The Mid-Continent Area Power Pool (MAPP) is the NERC subregional organization that includes Minnesota. MAPP has had three main functions: 1. a reliability council, responsible for the safety and reliability of the bulk electric system including system-wide planning functions; 2. a regional transmission group, responsible for facilitating open access of the transmission system; and, 3. a power and energy market, where MAPP members and non-members may buy and sell electricity.

At the end of 2001, MAPP's operational and planning functions for most of its members were transferred into a much larger regional transmission organization, called the Midwest Independent System Operator (MISO). MISO will take over the facilities planning (100 kV and above) for its member utilities. MAPP retains its reliability council function. When assessing transmission options for meeting the needs of the region, MISO planners are expected to look at a number of factors, including location of need, cost effectiveness, the ability to accommodate the diversity of generation sources, impact on the environment, and reliability.

Figure1: The Midwest Independent System Operator (MISO) Region



While MAPP has been, and MISO will be, responsible for regional long-range planning, the ultimate decision on whether a Minnesota-based project is needed to meet electric demand lies with the Minnesota Public Utilities Commission (PUC). The PUC must approve a Certificate of Need application before a major electric generation or transmission project can be built in Minnesota. Under the provisions of the Energy Security and Reliability Act, passed during the 2001 legislative session, utilities are required, every two years, to submit a transmissions project report to the PUC. The report is required to list the present and reasonably foreseeable future inadequacies in the transmission system in Minnesota and identify alternative means of addressing each inadequacy listed. The first transmission plan was submitted to the PUC on November 1, 2001. While the state's utilities submitted a joint report, none listed specific projects for approval at that time. The utilities indicated that they plan to submit certain transmission line projects individually for approval, as has been done in the past. The next plan is due on November 1, 2003.

Once the Minnesota Public Utilities Commission has issued a Certificate of Need for a project, the proposer must obtain a site or route permit from the Environmental Quality Board. Under limited circumstances, the proposer may opt to seek a site or route permit from local governmental units. Both processes involve environmental review with citizen and other stakeholder input.

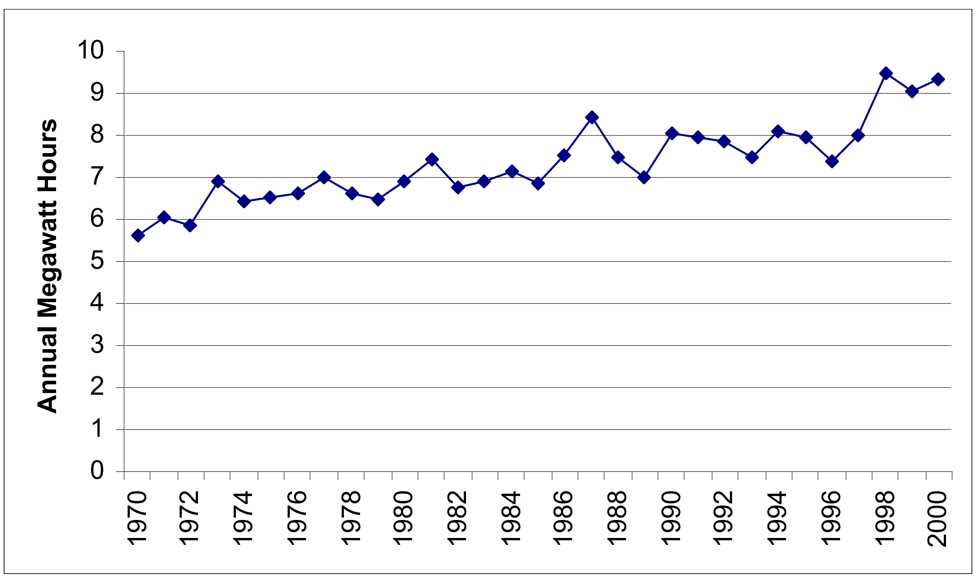
Current Needs for New Infrastructure

Growth in Electric Consumption

Since the mid-1960's, electric use in Minnesota homes has nearly doubled, from an average of 5 megawatt-hours (MWh) to 10 MWh per customer, per year (see Figure 2). While there have been extensive conservation measures used during this time, electrical use increased due to increased use of air conditioning, computers, larger refrigerators, and other appliances.

The growth in electricity use by all customers has increased even more in recent years. For example, over the ten years from 1990 to 2000, total annual electric consumption in the State grew from 49,355 gigawatt-hours to 62,532 gigawatt-hours, a 27 percent increase (Minnesota Dept. of Commerce, 2001).[3] Forecasts of future load growth indicate that the summer peak demand in the MAPP-U.S. region is expected to increase at an average rate of 1.9% per year during the 2001 – 2010 planning period (NERC, 2001). Given this level of growth, Minnesota has now reached the point at which new generation and transmission capacity is needed.

Figure 2: Weather-Normalized Electric Consumption per Minnesota Residential Customer 1970 - 2000



Proposed New Infrastructure

As noted above, MAPP forecasts of future load growth indicate that the summer peak demand in the MAPP region is expected to grow by an additional 16 percent in the next ten years. To meet this expected growth, the data reported to the MAPP planning process in the year 2000 show approximately 64 transmission expansion projects planned for Minnesota over the next ten years.

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[3] These figures are not adjusted for abnormally warm or cool weather in either year.

The planned construction activity for lines 115 kV and higher, as reported to MAPP, will result in approximately 434 miles of new or upgraded lines in Minnesota (See Table 1).

TABLE 1

Planned Transmission Lines and Transformers Reported to the MAPP Transmission Planning Subcommittee

Planned Transmission Lines and Transformers							Line Mile Estimates					Need Estimate (Sum = 100%)					
In Service Date (m/d/y)	MAPP Sub-region or Other Region	From:	To:	Circuit #	Voltage(s) (kV)	Number of Alternatives or None Reported (NR)	Reconductor or Thermal Increase	Rebuild or Conversion	New	Total Miles	Summer Rating (MVA)	Network	Gen Outlet	Transfer Capability	Improvement (Losses, Maint, Availability, etc)	A=Authorized P=Planned C=Completed W=Withdrawn	Reporting Source
11/1/05	RRV	Winger	Bemidji		115	NR	55.0			55.0	144	100				P	OTP
12/31/05	RRV	Frazee	Audubon		115	NR			48.0	48.0	161	100				P	OTP
5/1/00	UMV	Benton Co.	Benton Co. Tap		115	NR	4.1			4.1	300	80		20		A	NSP
5/1/00	UMV	Benton Co. Tap	Granite City		115	NR			1.0	1.0	300	80		20		A	NSP
10/1/00	UMV	I94 Ind Park	St. Cloud tap west	1	115	NR		6.0		6.0	224	100				A	GRE
11/1/00	UMV	Air Lake	Dodd Park		115	NR			4.0	4.0	300	100				A	GRE
11/1/00	UMV	Air Lake	Lake Marion		115	NR			6.5	6.5	337	100				A	GRE
12/1/00	UMV	Loon Tap	Waterville		161	1			5.0	5.0	191	100				A	NSP
12/1/00	UMV	Waterville	Loon Lake		161	1			11.0	11.0	191	100				A	NSP
5/1/01	UMV	Rutland	Winnebago	1	161	NR	15.0			15.0	225	100				A	ALT
5/1/01	UMV	Lakefield	Fox Lake	1	161	NR	22.0			22.0	225	100				A	ALT
5/1/01	UMV	Pleasant Valley	Austin	1	161	NR		17.0	6.0	23.0	444		100			A	GRE
5/1/01	UMV	Fox Lake	Rutland	1	161	NR	16.0			16.0	224	100				A	ALT
5/1/01	UMV	Fifth St	Main St		115	NR	0.7			0.7	300	100				P	NSP
5/1/01	UMV	Lakefield	Fox Lake	1	161	NR	22.3			22.3	219	100				P	ALT
5/1/01	UMV	Fox Lake	Winnebago	1	161	NR	31.6			31.6	224	100				P	ALT
6/1/01	UMV	Hutchinson	McLeod		115	NR			7.0	7.0	200	100				A	GRE
6/1/01	UMV	Champlin	Champlin Tap		115	NR	0.7			0.7	318	100				P	NSP
6/1/01	UMV	Gleason Lake	Gleason Lake Tap		115	NR	0.0				267	100				P	NSP
6/1/01	UMV	Goose Lake	Lexington		115	NR	9.2			9.2	318	100				P	NSP
6/1/01	UMV	Terminal	Rose Place		115	NR	2.9			2.9	318	100				P	NSP
10/1/01	UMV	Red Rock	(Stockyards)	2	115	3	0.5			0.5	318	100				P	NSP
10/1/01	UMV	(Stockyards)	Rogers Lake	2	115	3		5.8		5.8	318	100				P	NSP
5/1/02	UMV	Westgate	Glen Lake		115	2		3.6		3.6	318	100				P	NSP
5/1/02	UMV	Glen Lake	Gleason Lake		115	2		6.6		6.6	318	100				P	NSP
5/1/02	UMV	Willow Creek	Bamber Valley	1	161	3	2.7			2.7	202				100	A	RPU
5/1/02	UMV	Bamber	Cascade Creek	1	161	3		4.3		4.3	202				100	A	RPU

Planned Transmission Lines and Transformers							Line Mile Estimates					Need Estimate (Sum = 100%)					
		Valley															
5/1/02	UMV	Wilson	Bloomington	1	115	NR		2.2		2.2	192	100				A	NSP
5/1/02	UMV	Wilson	Bloomington	2	115	NR		2.2		2.2	192	100				A	NSP
6/1/02	UMV	Long Lake	Baytown		115	NR	6.9			6.9	318	100				P	NSP
6/1/02	UMV	Vermillion River	Empire		115	NR			6.0	6.0	200	100				P	GRE
6/1/02	UMV	Alma	Wabaco		161	NR	20.0			20.0	314			100		P	NSP
6/1/02	UMV	Silver Lk.	Rochester		161	NR	10.0			10.0	268			100		P	NSP
5/1/03	UMV	Arrowhead	Tripoli	1	345	5			165.0	165.0	900	100				P	MP
5/1/03	UMV	Chisago	Lawrence Creek		115	6			15.0	15.0	797	100				P	NSP
5/1/03	UMV	Lawrence Creek	Apple River		115	NR			23.0	23.0	797	100				P	NSP
5/1/03	UMV	Arden Hills	Lawrence Creek	1	115	NR		35.6		35.6	310	100				P	NSP
5/1/03	UMV	Parkers Lake	Plymouth	1	115	NR			4.3	4.3	300	100				A	GRE
5/1/03	UMV	Plymouth	Elm Creek	1	115	NR	3.5	6.0	2.5	12.0	300	100				A	GRE
5/1/03	UMV	Willmar	Paynesville	1	230	NR		27.0		27.0	600	82		9	9	P	NSP
6/1/03	UMV	Aldrich	Garfield		115	NR			2.0	2.0	70	100				P	NSP
6/1/03	UMV	Tanners Lake	Woodbury		115	NR	3.5			3.5	318	100				P	NSP
6/1/03	UMV	Rochester	Wabaco		161	NR	13.0			13.0	314	100				P	NSP
10/1/03	UMV	Big Swan	Hutchinson		115	NR			13.0	13.0	200	100				P	GRE
5/1/04	UMV	Bloomington	Airport	1	115	NR		2.8		2.8	318	100				A	NSP
5/1/04	UMV	Bloomington	Rogers Lake	1	115	NR		3.4		3.4	318	100				A	NSP
5/1/04	UMV	Airport	Rogers Lake	1	115	NR		3.4		3.4	318	100				A	NSP
5/1/04	UMV	Air Lake	Vermillion River		115	4			4.2	4.2	200	100				P	GRE
6/1/04	UMV	Terminal	Fairview		115	NR			2.9	2.9	318	100				P	NSP
6/1/04	UMV	Fairview	Western		115	NR			2.9	2.9	318	100				P	NSP
6/1/04	UMV	Aldrich	St. Louis Park		115	NR	5.4			5.4	318	100				P	NSP
6/1/05	UMV	Prairie Island	Alma		161	NR			54.0	54.0	445	100				P	NSP
5/1/06	UMV	Crooked Lake	Champlin Tap		115	NR	3.1			3.1	318	100				P	NSP
6/1/06	UMV	Elm Creek Xfmr		2	345-115	NR					448	100				P	NSP
6/1/07	UMV	Elm Creek	Crystal		115	NR			6.5	6.5	318	100				P	NSP
6/1/07	UMV	Crystal	Indiana		115	NR			6.5	6.5	318	100				P	NSP
6/1/07	UMV	Wilson	Nicollet		115	NR			2.5	2.5	70	100				P	NSP
6/1/07	UMV	Nicollett	Garfield (normal open)		115	NR			2.5	2.5	70	100				P	NSP
6/1/07	UMV	Panther	Franklin		115	NR			20.6	20.6	200	100				P	NSP
5/1/08	UMV	Loon Tap	Wilmarth		161	1		30.0		30.0	200	100				P	NSP
6/1/08	UMV	Inver Hills	Koch	2	115	NR			1.8	1.8	318	100				P	NSP
6/1/09	UMV	Eden Prairie	Edina		115	NR	3.4			3.4	318	100				P	NSP
6/1/09	UMV	Eden Prairie	Wilson		115	NR			8.0	8.0	318	100				P	NSP
6/1/10	UMV	Parkers Lake	Gleason Lk		115	NR	2.5			2.5	267	100				P	NSP

CHAPTER 3: ASSESSMENT OF EMF HEALTH EFFECTS RESEARCH

The Minnesota Department of Health (MDH) tracks EMF health effects research on a regular and ongoing basis to monitor for any new developments in EMF science and policy. This effort includes reviewing the latest research published in scientific journals; participating in conferences related to EMF, exposure assessment, and risk assessment; and consulting with leading EMF scientists affiliated with federal and international health agencies.

Staff of the Minnesota Department of Health conducted an evaluation of EMF health effects research. MDH's evaluation covered three areas: The historical body of published research on the topic; conclusions drawn by various scientific review committees based on review of the historical research; and more recent scientific studies published since the review committees developed their conclusions. Each of these is discussed below. MDH staff also consulted with leading EMF researchers at the National Institute of Environmental Health Sciences (NIEHS) EMF Research and Public Information Dissemination (RAPID) Program, the U.S. Environmental Protection Agency, and the National Toxicology Program to complete this evaluation. For additional information about EMF health effects research, refer to the web sites at the end of this chapter and references listed at the end of this report.

Overview of Historical EMF Health Effects Research

It is beyond the scope of this evaluation to conduct a historical review of all EMF research. Therefore, an overview is provided, primarily on the health effects of magnetic fields, to provide context for the discussion of review committee conclusions and the most recent research.

Epidemiological Studies

Research on the health effects of EMF began in the late 1960's and was originally focused on electric fields. In 1979, an epidemiological study reported a statistical association between surrogate indicators of residential magnetic field exposure (e.g., wire coding, the practice of estimating someone's exposure to magnetic fields based on the size of power line, type of line, and distance between a power line and someone's home) and two- to three-fold increases in leukemia risk among U.S. children (Wertheimer et al., 1979). A second study found similar results (Savitz et al., 1988). This early research brought the issue of magnetic field-related health risks to the attention of scientists and the public. More recent studies have used direct measurements (e.g., personal monitors, which participants wear all day to take regular measurements of the magnetic fields to which the person is exposed) to estimate magnetic field exposures. These studies show mixed results – i.e., some have reported no statistically significant association (Linet et al., 1997; Dockerty et al., 1998; McBride et al., 1999) and others have reported a weak association (Green et al., 1999; Schuz et al., 2001).

The inconsistencies in the epidemiological research have raised questions and concerns about whether there is a true "cause and effect" relationship between magnetic fields and leukemia or any other adverse health effects. Scientists generally have agreed that the epidemiological studies, by themselves, cannot establish a cause and effect relationship, and that additional evidence (e.g., laboratory studies) is needed to determine if there is a true relationship between magnetic fields and adverse effects.

Laboratory Studies

In recent years there have been several laboratory studies in animals conducted under controlled experimental conditions (NIEHS, 1999; NTP, 1999; Takebe et al., 2001). These studies have failed to provide support for a relationship between magnetic fields and adverse human health effects, even at high exposure levels. In addition, studies of isolated cells have failed to establish an understood biological mechanism of action for how magnetic fields may cause cancer (NIEHS, 1999; Takebe et al., 2001). These factors have raised doubt in the scientific community about what relationship, if any, exists between magnetic field exposure and childhood leukemia or any other adverse health effect.

Discussion

Many researchers have determined that important elements to confirm causality are currently lacking for EMF and human disease, including strength of association, consistency and specificity of observations, appropriate temporal relationship, dose response relationship, biological plausibility, and experimental verification. Researchers also have widely acknowledged the limitations of many magnetic field epidemiological studies, including the use of surrogate indicators (e.g., wiring code configurations) to estimate magnetic field levels; the small number of cases or subjects, particularly in high exposure categories; and the potential for bias due to factors related to selection, misclassification, recall, and confounding.

While some researchers disagree about the possibility of EMF causing adverse health effects, it is known that EMF associated with electrical power is extremely low frequency (60 hertz) relative to other types of fields commonly found in our environment (e.g., AM/FM radio, television, and cellular phone frequencies). Very high frequency fields, such as gamma rays, can break molecular bonds. Human exposure to gamma rays can cause direct DNA damage. Lower frequency fields such as microwaves do not cause direct DNA damage, but can have significant heating effects. Electrical power EMFs are not capable of causing direct DNA damage and are generally considered to have no thermal effects. Researchers continue to investigate possible mechanisms for how low frequency EMF may cause indirect biological effects. However, to date, there is limited evidence to conclude that indirect biological effects cause adverse health effects.

Conclusions of Scientific Review Committees

Several EMF scientific review committees have been convened by the U.S. Congress and by federal and international health agencies (NRC, 1996; NIEHS, 1999; NRPB, 2001;

IARC, 2001) to review and evaluate the extensive historical body of scientific literature on EMF health effects and to draw conclusions. The committees included leading EMF researchers and experts in multiple disciplines in the U.S. and abroad. The most prominent of the review committees and their conclusions are described and summarized below, starting with the earliest reviews and ending with the most recent.

American Physical Society (1995)

In 1995 the American Physical Society (APS), which is a national professional organization of U.S. physical scientists, concluded the following:

> Physicists are frequently asked to comment on the potential dangers of cancer from electromagnetic fields that emanate from common power lines and electrical appliances. While recognizing that the connection between power line fields and cancer is an area of continuing study by research workers in many disciplines in the United States and abroad, we believe that it is possible to make several observations based on the scientific evidence at this time. We also believe that, in the interest of making the best use of the finite resources available for environmental research and mitigation, it is important for professional organizations to comment on this issue.
>
> The scientific literature and the reports of reviews by other panels show no consistent, significant link between cancer and power line fields. This literature includes epidemiological studies, research on biological systems, and analyses of theoretical interaction mechanisms. No plausible biophysical mechanisms for the systematic initiation or promotion of cancer by these power line fields have been identified. Furthermore, the preponderance of the epidemiological and biophysical/biological research findings have failed to substantiate those studies that have reported specific adverse health effects from exposure to such fields. While it is impossible to prove that no deleterious health effects occur from exposure to any environmental factor, it is necessary to demonstrate a consistent, significant, and causal relationship before one can conclude that such effects do occur. From this standpoint, the conjectures relating cancer to power line fields have not been scientifically substantiated.
>
> These unsubstantiated claims, however, have generated fears of power lines in some communities, leading to expensive mitigation efforts and, in some cases, to lengthy and divisive court proceedings. The costs of mitigation and litigation relating to the power line/cancer connection have risen into the billions of dollars and threaten to go much higher. The diversion of these resources to eliminate a threat which has no persuasive scientific basis is disturbing to us. More serious environmental problems are neglected for lack of funding and public attention, and the burden of cost placed on the American public is incommensurate with risk, if any.

National Research Council (1997)

In 1991 the National Research Council convened an expert committee with experience in several scientific disciplines. The committee reviewed and evaluated the existing scientific information on the possible effects of exposure to electric and magnetic fields on the incidence of cancer, on reproduction and developmental abnormalities, and on neurobiological response, as reflected in learning and behavior. The committee summarized its conclusions in its 1997 report, "Possible Health Effects of Exposure to Residential Electric and Magnetic Fields:"

> Based on a comprehensive evaluation of published studies relating to the effects of power frequency electric and magnetic fields on cells, tissues, and organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard. Specifically, no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer, adverse neurobehavioral effects, or reproductive developmental effects.
>
> The committee reviewed residential exposure levels to electric and magnetic fields, evaluated the available epidemiologic studies, and examined laboratory investigations that used cells, isolated tissues, and animals. At exposure levels well above those normally encountered in residences, electric and magnetic fields can produce biologic effects (promotion of bone healing is an example), but these effects do not provide a consistent picture of a relationship between the biological effects of these fields and health hazards. An association between residential wiring configurations (called wire codes) and childhood leukemia persists in multiple studies, although the causative factor responsible for that statistical association has not been identified. No evidence links contemporary measurements of magnetic-field levels to childhood leukemia.

National Institute of Environmental Health Sciences (1999)

In 1992 the U.S. Congress instructed the National Institute of Environmental Health Sciences (NIEHS) to direct a program of research and analysis to evaluate the potential for health risks from EMF exposure. In 1999 the NIEHS released its report, "Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields." It is based on both review of the historical literature and results of NIEHS-sponsored studies. The NIEHS concluded:

> The scientific evidence suggesting that ELF-EMF [Extremely Low Frequency Electric and Magnetic Fields] exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the

epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of small increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic findings of biological effects (including increased cancers in animals) have been reported. No indication of increased leukemias in experimental animals has been observed.

The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given the weak magnitude of these increased risks, some other factor or common source of error could explain these findings. However, no consistent explanation other than exposure to ELF-EMF has been identified.

Epidemiological studies have serious limitation in their ability to demonstrate a cause and effect relationship whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to ELF-EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but cannot completely discount the epidemiological findings.

The NIEHS concludes that ELF-EMF exposure cannot be recognized at this time as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of risk to currently warrant concern.

Institute of Electrical and Electronics Engineers, Committee on Man and Radiation (2000)

In 1999 the Institute of Electrical and Electronics Engineers, Engineering in Medicine and Biology Society convened the Committee on Man and Radiation (COMAR). This committee included experts on health and safety issues related to electromagnetic fields, from power line through microwave frequency ranges. The committee concluded in their technical information statement:

> In recent years concerns have been raised about the biological effects of exposure to electric and magnetic fields at extremely low frequencies (ELF), particularly those associated with the distribution and utilization of electric power. In 1989, the Institute of Electrical and Electronics Engineers (IEEE) issued an "Entity Position Statement" which stated that "there is not enough relevant scientific data to establish whether common exposure to power-frequency fields should be considered a health hazard" and that "there is general agreement that more research is needed to define safe limits of human exposure to power-frequency fields." After examination of relevant research reports published during the last ten years, COMAR concludes that it is highly unlikely that health problems can be associated with average 24-hour field exposure to power frequency magnetic fields of less than 1 microT (10 mG). Good laboratory evidence shows that magnetic fields 100 to 10,000 times higher than this level, either ELF sinusoidal or pulsed, can induce a variety of biological effects, including beneficial health effects such as bone or tissue healing. Many of the reports of effects of weaker fields should be considered preliminary, as some observations have not been reproduced in different laboratories, while others, observed in cells, have not been clearly connected to effects in intact animals. Also, the means of interaction of low-level ELF fields with cells, tissues or laboratory animals is not fully understood; therefore the health impacts of such weak fields on intact animals and humans, if any, cannot be predicted or explained. Further research is needed to confirm or negate reports of effects of weak fields, and to determine mechanisms and relevance of these effects to actual health hazards. Continued study in this complicated area will enhance our understanding of biological systems, as well as help identify levels and types of ELF exposure that may be deleterious to human health.

National Radiological Protection Board (Advisory Group on Non-Ionizing Radiation) (2001)

In March 2001, the British National Radiological Protection Board, Advisory Group on Non-Ionizing Radiation, conducted an extensive review of the EMF research. The Advisory Group concluded:

> Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukaemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK [United Kingdom]. In the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children. Unless, however, further research indicates that the finding is due to chance or some currently unrecognized artifact, the possibility remains that intense and

prolonged exposures to magnetic fields can increase the risk of leukemia in children.

International Agency for Research on Cancer (2001)

In June 2001, the International Agency for Research on Cancer (IARC) convened a meeting of 21 scientific experts from 10 countries to evaluate possible carcinogenic hazards to humans from exposures to EMF. They concluded:

> Since the first report suggesting an association between residential electric and magnetic fields and childhood cancer, notably leukemia, was published in 1979, dozens of studies have examined this association. Overall, for the vast majority of children who are exposed to residential ELF [extremely low frequency] magnetic fields less than 0.4 microtesla [4 milligauss], there is little evidence of any increased risk for leukemia. There is no evidence that electric fields are associated with childhood leukemia, and there is no consistent relationship between childhood brain tumors and residential ELF electric and magnetic fields. However, pooled analyses of data from a number of well conducted studies show a fairly consistent statistical association between childhood leukemia and power-frequency residential magnetic field strengths above 0.4 microtesla, with an approximately two-fold increase in risk. This is unlikely to be due to chance, but may be affected by selection bias. Therefore, this association between childhood leukemia and high residential magnetic field strengths was judged *limited evidence* for excess cancer risk in exposed humans. [Emphasis in original.]
>
> There is no consistent evidence that residential or occupational exposures of adults are related to excess risks of cancer at any site [in the body], although in one Swedish study combined residential and occupational exposures were associated with a significantly increased risk for leukemia subtypes except chronic lymphocytic leukemia. Evidence for excess cancer risks of all other kinds, in children and in adults, as a result of exposure to ELF electric and magnetic fields was considered *inadequate*. [Emphasis in original.]
>
> Numerous studies to investigate carcinogenicity of magnetic fields have been conducted in experimental animals. These have included long-term bioassays of exposures to magnetic fields alone, and exposures of rats and mice to magnetic fields in combination with known carcinogens. Bioassays of magnetic fields alone generally were negative, although one study that was conducted in both mice and rats of both sexes showed non-exposure related increases in thyroid C-cell tumors in male rats only. Multistage carcinogenesis studies showed no consistent enhancement of chemically initiated mammary tumors in rats or of skin tumors in mice. Magnetic fields had no effects on the incidence of chemically initiated liver tumors in rats or of leukemia/lymphoma in mice or rats. Overall, evidence of carcinogenicity of ELF magnetic fields in experimental animals was judged inadequate. No data on carcinogenicity to animals of static magnetic fields, or of static or ELF electric fields, were available to the working group.

> Although many hypotheses have been put forward to explain possible carcinogenic effects of ELF electric or magnetic fields, no scientific explanation for carcinogenicity of these fields has been established.
>
> Overall, extremely low frequency magnetic fields were evaluated as possibly carcinogenic to humans (Group 2B), based on the statistical association of higher level residential ELF magnetic fields and increased risks for childhood leukemia. Static magnetic fields and static and extremely low frequency electric fields could not be classified as to carcinogenicity to humans (Group 3).

Note that the term "possibly carcinogenic to humans" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals. This classification is the weakest of three categories used by IARC to classify potential carcinogens.

Japan EMF Research Program (2001)

In the 1990's Japan conducted an EMF research program comparable in scope and magnitude to the NIEHS EMF RAPID program. The focus of this program was laboratory testing for possible cancer effects such as changes in gene expression or increased risks for tumors. In 2001 the results of this research program were published in the book, *Biological and Health Effects from Exposure to Power-Line Frequency Electromagnetic Fields: Confirmation of Absence of Any Effects at Environmental Field Strengths* (Takebe et al., 2001). The researchers concluded:

> By the middle of 1999, as mentioned in the EMF RAPID report, there was little evidence for any adverse health effects from EMF exposure. About half of the epidemiological studies have suggested possible health effects, but almost all of the experimental studies with animals have been negative. Thus it appears there is little possibility of finding new adverse health effects from EMF in the future. Very high intensity EMF can have certain biological effects, but they occur only with EMF more than 10,000 times higher than those found in real-world environments. Furthermore, even with the biological indicator which gave the positive results with 400 mT [4,000,000 milligauss] for 1 hour, elongated exposure with 5 mT [50,000 milligauss] for 6 weeks did not yield any effect. We conclude that adverse human health effects as a result of environmental power-frequency EMF either do not occur or that they are undetectable because they occur so rarely they cannot be separated by other processes.

Health Council of the Netherlands (2001)

In May 2001 the Health Council of the Netherlands, Electromagnetic Fields Committee, completed an annual review of the research on possible health effects of exposure to electromagnetic fields (HCN, 2001). This review included several recently published EMF studies, including two meta-analyses (Ahlbom et al., 2000 and Greenland et al., 2000).

> The committee concludes that these recent meta-analyses show a consistent association between relatively high measured or calculated magnetic field strengths and an increased risk of childhood leukemia. However, from an epidemiological point of view, an association with a relative risk of smaller than 2 is to be considered weak. Furthermore, the committee does not think that either 0.3 uT [3 mG] or 0.4 uT [4 mG] should be regarded as a definite threshold field strength, above which the risk is suddenly increased. This view is based upon the belief that it is not appropriate to consider measured and calculated fields strengths in the same light. Where researchers have obtained field strength data by measurement, the contributions made by all sources inside and outside the home are taken into account, with the result that the study data is reasonably consistent with overall exposure. Where calculated data is used, however, only the strength of the field generated by a single external source (typically a high voltage power line) is considered. In studies using calculated field strength data actual exposure is therefore underestimated. Furthermore, it is apparent from research carried out in the UK and elsewhere that in a large proportion of homes where relatively high field strengths occur, the fields are not primarily attributable to external sources such as high-voltage power lines (Day 99).
>
> The committee would emphasise that there is no known mechanism that could account for the association referred to above. Because the association is only weak and with out a reasonable biological explanation, it is not unlikely that it could also be explained by chance or by an artefact. The committee therefore sees no reason to modify its earlier conclusion that the association is not likely to be indicative of a causal relationship.
>
> It therefore remains the committee's belief that it is not likely that children (or adults) living near to high-voltage power lines are at risk through exposure to electromagnetic fields generated by those lines. This view is consistent with that of the Advisory Group on Non-ionising Radiation – a committee of the UK's National Radiological Protection Board, chaired by Sir Richard Doll – as published in early March 2001.

MDH Review of Recent Scientific Literature

As part of its ongoing evaluation of EMF research, MDH completed a literature review of research published since the 1999 NIEHS scientific review committee report. This review included over 50 studies published in scientific journals and/or presented at the June 2001 International Bioelectromagnetics Society Meeting. It is beyond the scope of this assessment for MDH to comment on all reviewed EMF studies. The comments below focus on selected recent EMF studies that are most prominent. It is important to recognize that these studies are a small fraction of the total EMF research published to date and of EMF research reviewed by the scientific committees convened by federal and international health agencies to date.

Canadian Studies

Two Canadian studies published in 1999 demonstrate the inconsistencies observed in the EMF epidemiological research (Green et al., 1999; McBride et al., 1999). Green et al., evaluated childhood leukemia and EMF exposure in Ontario, Canada. This study showed a weak association between contemporary measured fields outside residences and childhood leukemia. This study also found a positive association when comparing fields measured with personal monitors and childhood leukemia. However, there was no association with childhood leukemia for contemporary fields inside residences. In addition, when using wire codes (as with Wertheimer and Leeper, and Savitz) there was no association with cancer. At the same time in 1999, McBride conducted a much larger study in Ontario. This study found no association with childhood leukemia for personal monitors, contemporary measured fields inside residences, historic magnetic fields or wire codes.

National Toxicology Program Studies

In 1999 the National Toxicology Program conducted a two-year whole body exposure animal study to investigate possible effects from 50-60 hertz magnetic fields (NTP, 1999). The highest field intensity (10,000 milligauss) was considered approximately 5,000 fold greater than what was considered high intensity for homes in epidemiological studies in humans. Results showed no effects on survival and body weights and no increased incidences of neoplasms at sites for which epidemiological studies have suggested an association with magnetic fields.

British Journal of Cancer

In September 2000 researchers published a pooled analysis of EMF studies in the British Journal of Cancer (Ahlbom et al., 2000). The analysis included data from nine studies that had been conducted in Europe, Canada, New Zealand, and the U.S., including data from the 1999 McBride et al. study. Pooling data in this fashion provides a greater number of subjects and yields greater statistical power when conducting analyses.

The study reported a weak association between exposure to power frequency magnetic fields greater than 4 milligauss and childhood leukemia. Specifically, the study found that children with residential exposures to magnetic fields greater than 4 milligauss had a statistically significant relative risk estimate of two for childhood leukemia. The authors attempted to adjust for several possible confounding factors, including socioeconomic status, type of dwelling, urban or rural setting, and several others. Adjustment for these factors made little difference in the relative risk values. If there are confounding factors that would influence the result, they have yet to be identified. The authors pointed out that selection bias probably accounted for some of the elevated risk estimates, and concluded that future research should address selection bias, confounding factors, and the fact that their results were based on a very small number (0.8 percent) of leukemia cases in the high exposure groups. A second analysis of some of the same pooled studies reported similar results and limitations in a separate publication (Greenland et al., 2000).

The two analyses of pooled data include many of the same studies and their conclusions are similar – there appears to be a statistically significant increased risk of childhood leukemia at the highest exposure categories. However, authors in both studies acknowledged that these results were based on small numbers of subjects in the highest exposure category, and both recommend that future EMF studies include more subjects at these levels, since there is little or no evidence of an association at levels to which most people are exposed. MDH staff conducted an evaluation of these studies and concluded that these studies represent no new data, but a recombining and re-analysis of data from selected studies that have been previously published.

California EMF Program – Risk Evaluation Report

In 2001 the California Department of Health Services (CDHS), California EMF Program, released a *draft* EMF Risk Evaluation Report (CDHS 2001). This report was based on an evaluation conducted by three CDHS reviewers who examined possible associations between magnetic fields and 13 health conditions. The reviewers reported their opinions regarding the degree of confidence that the statistical associations between magnetic fields and the various health conditions might be causal. (For their conclusions, see the CDHS report: http://www.dhs.ca.gov/ps/deodc/ehib/emf/RiskEvaluation/riskeval.html)

Following the release of the draft report, CDHS solicited public comments and convened meetings with stakeholders and a scientific review panel. Comments were received from concerned citizens, electrical utilities, advocacy organizations, and several U.S. and international scientists (CDHS 2002).

While some scientists praised the California reviewers for using a novel approach, other researchers raised substantial concerns regarding the report's conclusions, and more fundamentally, the process used to conduct the evaluation (CDHS 2002). Based on these comments and a review of the report, MDH concluded that there is no scientific consensus at this time on the report's conclusions, including the degrees of confidence that the reviewers assigned regarding a causal relationship between EMF and adverse health effects.

MDH also concluded that there are some significant limitations in California's EMF evaluation. For example, the California reviewers failed to adequately address the lack of supporting data from animal laboratory studies and the lack of a plausible biological mechanism of how EMF may cause harm in their evaluation. Furthermore, they failed to adequately address several well-recognized limitations (e.g., selection bias, confounding, exposure misclassification) in EMF epidemiological research.

In contrast with the California evaluation, recent scientific EMF panels (i.e., International Agency for Research on Cancer, National Radiological Protection Board (UK), National Institute of Environmental Health Sciences, and Netherlands Health Council) have all considered the lack of supporting data in animals and cellular studies to be an important factor in evaluating a possible causal relationship between EMF and adverse health effects. These panels also have recognized the importance of elucidating a plausible biological mechanism to determine causality, particularly in light of the limitations of EMF epidemiological research.

MDH also has concluded that there are several important distinctions between California's evaluation process and the processes used by other scientific EMF review panels. The California evaluation was conducted by three reviewers, all from the same agency, and all with primary expertise in epidemiology. Other recent scientific EMF panels (listed above) have taken advantage of a broader review panel selected from leading U.S. and international health agencies and research organizations, representing expertise in a wide variety of disciplines (e.g., epidemiology, cellular biology, physics, statistics).

At this time it is not clear how California decision-makers will use the CDHS EMF Risk Evaluation report. A revised report is expected to be completed in 2002. MDH will continue to track EMF developments in California, as well as other states. (For more information about EMF activities in California and other states, see the Appendix).

Future Research

EMF research is continuing in the U.S. and abroad, as new methods for studies are developed to improve exposure assessment, to control for confounding and other types of bias, and to investigate possible biological mechanisms. NIEHS supports some limited extramural EMF research; however, their 5-year EMF RAPID Program has concluded, and there do not appear to be any plans to expand EMF (60 hertz) federal research at this time (NIEHS, 2001). Japan has also concluded their EMF research program; however there are some isolated studies that are ongoing.

In 2003 the World Health Organization (WHO) International EMF Project is expected to complete an assessment of non-cancer EMF health risks (WHO, 2001). This project is working in collaboration with international agencies and organizations to pool resources and knowledge about EMF; to identify gaps in knowledge; recommend focused research programs; conduct updated critical reviews of the scientific literature; and develop materials for risk communication. Note that WHO defines EMF broadly to include static, extremely low, intermediate, and radio frequency fields (up to 300 gigahertz). (For more information about the World Health EMF Research Project, see the web site: http://www.who.int/peh-emf).

MDH will continue to monitor important EMF health effects research. Future research efforts should focus on identifying possible biological mechanisms and identifying what aspect of a field may be hazardous. Without this information, scientists will be unable to provide policy guidance about what aspect of a field (e.g., frequency, intensity, polarization, harmonization), if any, would be appropriate to mitigate.

For More Information

For more information about EMF health risks, refer to the web sites listed below:

Minnesota Department of Health, Environmental Health Division
http://www.health.state.mn.us/divs/eh/radiation/emf/index.html

National Institute of Environmental Health Sciences, EMF RAPID Program
http://www.niehs.nih.gov/emfrapid/home.htm

World Health Organization, International EMF Research Project
http://www.who.int/peh-emf/

Medical College of Wisconsin, Electromagnetic Fields and Human Health
http://www.mcw.edu/gcrc/cop/powerlines-cancer-FAQ/toc.html

Bioelectromagnetics Journal, EMF Research Abstracts (see link at bottom of web page for BEMS 23rd annual meeting, St Paul, Minnesota)
http://www.bioelectromagnetics.org/pubs.html

Wisconsin Public Service Commission, EMF Background (adobe acrobat)
http://psc.wi.gov/consumer/electric/document/brochure/6002b.pdf

Health Council of the Netherlands
http://www.gr.nl/engels/welcome/index.htm

California Department of Health Services, EMF Program
http://www.dhs.ca.gov/ps/deodc/ehib/emf/

Virginia Department of Health, Monitoring of Ongoing Research on the Health Effects of High Voltage Transmission Lines, 2000 (Final Report)
http://www.vdh.state.va.us/hhcontrol/highfinal.pdf

CHAPTER 4: REGULATORY APPROACHES TO ADDRESS EMF ISSUES

The questions surrounding EMF present a common but difficult challenge to government regulators: Should government officials limit exposure to an agent for which there is only limited evidence of public harm? And if so, what guidelines should be used to determine the extent and type of government regulation? This chapter outlines several possible frameworks for making regulatory decisions regarding the potential for harm from EMF and presents the advantages and disadvantages of applying them to EMF exposure.

The Range of Regulatory Principles

This section outlines the range of regulatory principles that could be used as a basis for regulating EMF exposure. It refers to a "range" of principles because there is a spectrum of possible frameworks for making public policy decisions. Especially in the face of uncertainty (such as the health effects of EMF), the underlying principle on which a decision is based will have a great effect on the final decision.

The following principles are listed from those that would require the least government oversight to those that would require the most.

Virtual Certainty

Virtual certainty is based primarily on the idea of limited government. Under this viewpoint government should not regulate activities in the private sector unless the vast majority of scientists are virtually certain that there is a problem. This framework would tend to require a high degree of confidence on the part of most scientists that the harm occurs and that exposure is likely to result in harm. A lack of confidence by most scientists would indicate that no action should be taken by regulators.

Advantages: Does not expend government resources on issues that may have no real environmental impact.
Encourages technological innovation by allowing all but clearly dangerous products to be used and marketed.

Disadvantages: Has the potential to cause great environmental harm before "virtual certainty" of harm is attained (e.g., DDT, PCBs).
The correction of the harm may cost more than prior prevention.
The burden of proof is on those being harmed.

Buyer Beware

This is a common concept (also known as *caveat emptor*) most often applied to the market for commercial goods. This principle places much of the burden for what is sold on consumers themselves, assuming that producers will not supply something for which there is no demand. In the context of electrical power, this principle assumes that consumers would choose to use less electricity, or would pay more to have power lines buried or moved, if they felt these actions were more advantageous than exposure to EMF. Government regulation under this principle is primarily used to ensure that the markets work correctly. This is accomplished by ensuring that buyers have all information necessary to make an informed decision and by equalizing the market power of the participants.

Advantages:
- Maximizes individual rights and choices.
- Consistent with the principles of capitalism.
- Does not impose government solutions on producers or consumers.

Disadvantages:
- Expects citizens to remain informed on a wide variety of possible harms, which is not realistic.
- Assumes that consumers can make choices that avoid the harm, which is not always true.
- Does not allocate costs properly when the person experiencing the harm (e.g., harm from production or distribution practices) is not the same as the person buying the product.

Utilitarian Perspective

This perspective emphasizes results and seeks to promote choices that provide the most good for the most people at the least cost. This principle is closely linked to cost/benefit analysis, since the most obvious way to demonstrate utility is to quantify variables into monetary units and tally the results. This approach works best when the variables can be readily quantified and the distribution of costs and benefits is spread fairly evenly throughout a population. This approach encounters increasing difficulty when there are valuation problems (e.g., valuing death or disability), uncertainty of risk, and uneven distribution of costs and benefits throughout society.

Advantages:
- Attempts to compare true benefits to true costs.
- Attempts to maximize the collective good.
- Recognizes that government resources are limited and money should be spent in ways that can make the biggest impact on public welfare.

Disadvantages:
- Often creates controversy when trying to place monetary value on human life or quality of life.
- Must rely on assumptions and estimates when levels of risk are unknown. This can greatly increase the range of possible values and make application of cost/benefit principles less useful.
- Cannot adequately address issues of justice when certain segments of the population are asked to bear a harm (or potential harm) in order to achieve an overall public good.

Precautionary Principle

The precautionary principle has been around in the form of maxims for a long time. "Better safe than sorry" and "Look before you leap" could be considered succinct versions of the precautionary principle. The application of this principle to environmental issues has happened more recently, primarily in European law and International law. Some version of the principle has been included in several conventions and treaties, including the 1985 Vienna Convention of Ozone Depleting Substances and the Rio Declaration on Environment and Development.

Because there are a variety of governments and citizens discussing this principle and how it should be applied, there are variations in how the principle is stated. One of the recent and often-quoted versions of the precautionary principle was developed during a 1998 conference held at the Wingspread Conference Center in Racine, Wisconsin:

> When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof. The process of applying the Precautionary Principle must be open, informed, and democratic, and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action.

While this principle has received less attention in the United States than in Europe, U.S. officials are discussing it. In an October 2000 speech at the National Academy of Sciences in Washington, D.C., then-governor of New Jersey (now EPA Administrator) Christine Todd Whitman stated that:

> Policymakers need to take a precautionary approach to environmental protection.... We must acknowledge that uncertainty is inherent in managing natural resources, recognize it is usually easier to prevent environmental damage than to repair it later, and shift the burden of proof away from those advocating protection toward those proposing an action that may be harmful.

A similar concept, commonly called prudent avoidance, has often been used in the context of EMF exposure. This concept is very similar to the precautionary principle in suggesting that one should avoid any activity or exposure about which there are questions of safety or health, at least to the extent that the activity can be avoided easily or cheaply. However, prudent avoidance generally does not carry the same connotations of shifting the burden of proof to the proposer of the activity in question.

While there appears to be some agreement that the precautionary principle is needed, important questions remain as to how it will be applied to various health and environmental issues.

Advantages: Protects the public from harms that are suspected but not yet proven.

Shifts the burden of proof to those who stand to benefit from the use of a new technology, chemical, or drug.
Emphasizes the inclusion of all affected parties in deciding the extent of any regulation.

Disadvantages: May stifle development of new technologies and products that are ultimately shown to be safe.
Science cannot prove the null hypothesis - it could be a high burden to prove no harm, depending on how that condition is applied.
More difficult to apply this principle to existing technologies that are common and on which people rely heavily, such as electricity.

Environmental justice

Other considerations may impact the regulatory approach taken, regardless of which perspective one applies. A prime example is the concept of environmental justice. In 1994, President Clinton issued Executive Order 12898 regarding federal actions to address environmental justice in minority and low-income populations. The order states that "each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations …." While there is no similar directive at the state level, policy makers have expressed an interest in incorporating this concept into state-level decisions as well.

This principle relies on a democratic or egalitarian view of the world, recognizing that there are certain rights that all citizens should be able to enjoy. According to the U.S. Environmental Protection Agency, one of these rights is the right of "all people to live in clean, healthy, and sustainable communities."

As with the regulatory principles above, there are certain advantages and disadvantages in applying this concept:

Advantages: Strives to provide all people with a basic level of environmental protection.
Puts the resources of government to work for people who are the least likely to have resources to protect themselves from harm.
Emphasizes the education and inclusion of affected communities in deciding the need for, and extent of, any regulation.

Disadvantages: Not clear how to apply this principle when environmental harm is distributed throughout society rather than concentrated in minority or low-income communities.

How one defines “clean, healthy, and sustainable” is a matter of interpretation, and therefore does little to address certain core issues.

Does not answer the question of what to do in the face of harms that are possible but not yet proven.

In summary, decision-makers have several possible options in deciding whether or how much to regulate EMF. Each approach has advantages and disadvantages. At one extreme, regulators can require virtual certainty of harm before they address it. At the other extreme, proposers of a project would need to demonstrate its safety before regulators would allow them to proceed. Choosing an approach at any point along this continuum depends largely on how lawmakers and regulators view the role of government and how it should apply to a regulated good like electricity.

CHAPTER 5: EMF EXPOSURE MITIGATION OPTIONS

Electric and magnetic field exposures in individual residences can be attributed to fields from adjacent power lines, fields from electrical wiring in the home, fields from the operation of electrical appliances, or a combination of all three. In most cases the fields originating from within the house are not the subject of public regulation (with the possible exception of building code violations). Since this paper is focused on public policy decisions regarding EMF, most of this chapter will focus on mitigating fields from transmission and distribution lines. However, internal sources of EMF can contribute as much or more to EMF exposure than power lines.

Mitigation of EMF from Transmission Lines

Electric utilities have a variety of methods for reducing EMF exposures when they upgrade or install transmission and distribution lines. The main methods for mitigating EMF include increasing distance from the line, using phase cancellation, shielding, and limiting voltage and current flow levels.

Distance

The amount of EMF exposure is related to the distance from a power line source. The strength of both the electric and magnetic fields from traditional overhead transmission lines is inversely proportional to the square of the distance from the source. Therefore the level of exposure decreases rapidly with increasing distance from the source conductors. Utilities' primary methods of increasing distance include increasing the conductor height above ground, increasing the width of the right of way, or relocating the line to a route more distant from inhabited areas.

Phase cancellation

Phase cancellation can significantly reduce EMF from transmission lines. This can be accomplished by bringing the conductors closer together, vertical double circuiting, or placing independent wire conductors between the transmission line and an area of exposure. Phase cancellation is most effective when the three phases have the same current flow.

> <u>Conductor separation</u>**.** A commonly used method to reduce EMF is to decrease the distance between the conductors (the three wires seen between the poles and towers). This reduces the magnetic fields created by each of the three conductors because the fields are out of phase with each other and thus cancel each other. However, bringing the conductors closer together requires the supporting structures to be closer together to prevent arcing and shorting out between conductors. This adds additional construction and material cost to the line.
>
> There has been some research to develop an overhead 110-kV transmission line with insulated conductors. Instead of the conventional bare conductors, the

transmission lines use those covered with a thin layer of plastic. As a result, they are able to touch each other in high winds without shorting. Consequently, phase conductors can be situated closer to each other, allowing transmission towers to be more compact. EMF from this configuration has been measured as much as one-third below those from existing horizontally configured lines. The main goal of the research was to find a solution for upgrading lines in densely populated regions; the reduction of EMF is an added bonus. Since this technology is still in the testing phase, its effectiveness and costs are not known.

Undergrounding. Undergrounding (burying) transmission lines always reduces the electric field and reduces the magnetic field if the conductors are placed in close proximity to each other (see conductor separation). The electric field is reduced by the electrical insulation around the conductor. The magnetic field is not reduced by the insulation, but the insulation allows the conductors to be placed close to each other, which significantly reduces the magnetic field through phase cancellation. This requires equal current flow in each phase.

If there is not balanced current flow, the magnetic field from underground lines increases. This can be significant even with minor imbalances in current flow, because the underground line is usually only three and a half to five feet underground. An overhead line usually has a minimum of twenty-five to thirty-five feet of clearance above ground and an average clearance between structures of thirty-five to fifty feet. While utility engineers prefer to have balanced current flow through the lines, it is not always possible to achieve this result. Generally, transmission lines are more likely to maintain balanced current flow than are distribution lines.

Undergrounding has not been used for transmission lines for several reasons. First, the cost is two to five times or more the cost of an overhead line, depending on location and circumstances. Second, such circuits are more difficult and costly to maintain and repair. Third, an underground line poses system operational limits because the insulation does not allow efficient cooling of the conductors and the high capacitance of the closely spaced conductors in the pipe can reduce its current-carrying capacity.

Vertical configuration. Lines with current-carrying conductors positioned vertically on power line structures produce lower magnetic fields than power lines with conductors positioned horizontally.

Vertical double circuiting**.** A common transmission line configuration is the vertical double-circuit, where a set of three conductors is attached, one above the other, to each side of the transmission tower. The three cables comprise the three phases of the power network, with each conductor carrying current. Electric utilities use the letters A, B and C to denote a three-phase circuit, with each letter representing one cable and its phase. At little extra cost, electromagnetic fields can be reduced by 50 percent or more by reversing the phase order of the other circuit (i.e., C-B-A). Partial cancellation of both magnetic and electric fields is thus achieved. The effectiveness of this arrangement is also dependent on the current flowing through each circuit.

Independent out-of-phase fields. Another less used approach is to generate out-of-phase fields from a separate conductor placed between the transmission line and the area where field reduction is desirable. Fields equal to and opposite in magnitude from those emitted by the power line would be generated to cancel the fields from the power line. This approach is not very practical except for specific locations.

Shielding

The electric field component of EMF is easily shielded by most structures. However, the magnetic fields are difficult to contain with shielding. Some materials exist that have magnetic shielding characteristics, but the expense of these items is such that the application is mostly limited to small projects and specific locations.

Reduction in voltage or current levels

Electric field levels are proportionate to the operating voltage of the power line. Downsizing the voltage class of the facility will reduce electric field levels. Reducing voltages is not a very practical alternative for limiting electric fields because the capacity of the line is also reduced and all the transformers connected to the line would have to be replaced.

Magnetic fields are proportionate to the level of amperage on a given conductor. The amperage will normally fluctuate according to system loading activity and any line will have a daily profile of loading levels, and a corresponding fluctuating magnetic field generation level. The maximum current flow is normally limited by the thermal limit of the conductor or some other system limitation such as the rating of a transformer or switch. Limiting the current to limit the maximum magnetic field would also limit the power carrying capacity of the line. Adding an additional parallel line would reduce the current on the existing line but would add additional right of way.

Deliberately reducing the voltage or the amperage of a transmission line below its designed capability results in a reduced return on investment and increases the need for additional lines. Underutilization of infrastructure can ultimately lead to higher utility rates for customers.

Conservation

Encouraging conservation is a non-regulatory way to reduce electrical demand, resulting in lower power flow levels and reduced EMF. Conservation may also delay or eliminate the need for additional power lines in certain areas.

Mitigation of EMF from Primary Distribution Lines

The principles for managing EMF for primary distribution lines are identical to that noted above for transmission lines, including increasing distance, phase cancellation, and undergrounding.

Primary distribution right-of-way is normally much narrower than transmission right-of-way, usually 10 feet wide compared to 50 or 100 feet for transmission right-of-way. Minimum clearances of distribution lines to other facilities are dictated by the National Electric Safety Code. These easements are normally located along streets or rear lot lines and alleys adjacent to the homes and businesses obtaining service. Because of the narrow right of way and the lower clearance, homes and businesses are closer to the distribution line and thus are likely to experience higher magnetic fields.

The size of the magnetic field from a distribution line depends on the amount of current flowing on that line, which again is dependent on the use of electricity. Generally current flows on primary distribution lines are lower than on transmission lines, thus creating lower magnetic field levels. With the lower voltages of distribution power lines, conductors can be located much closer together. This allows greater magnetic field cancellation between phase wires of a three phase feeder line.

If there is a concern about magnetic fields from overhead circuits, the conductors can be mounted on higher poles and/or moved from eight foot wooden cross arms to post insulators (armless construction) for a reduction in magnetic fields. In addition, municipal governments can mandate greater clearances of distribution lines from streets, alleys, and other structures. In the case of newly platted subdivisions, primary distribution circuit layout is designed and reviewed by municipal authorities before being built. As a result, utilities can be made aware of the planned location of new schools and other municipal facilities before the circuits are built.

In most new urban subdivisions, primary distribution conductors are buried. The conductors are normally buried along the same routes where overhead lines would have been placed due to the fact that transformers must be located adjacent to property lines for electric service to individual homes and commercial customers. With the closer spacing of the insulated conductors used in direct burial cable, magnetic fields at approximately ten feet or more from the line are significantly less than equivalent overhead lines carrying the same current level. Fields directly over a buried line are higher than the fields directly under an overhead line, since the buried line is only a few feet underground. As with transmission, if the current flow is not balanced in all three phases, cancellation will not be as effective.

Mitigation of EMF from within the Home

Common contributing sources of magnetic fields within the home are improper grounding and improper wiring of the home electrical system, which can often be addressed by properly following electrical codes. Older homes may have higher ambient exposures due to the type of wiring, for example knob and tube wiring. These types of issues must be assessed on a case-by-case basis.

Additional sources of EMF include many common household appliances, including microwave ovens, vacuum cleaners, analog clock radios, hair dryers, and electric blankets. For example, household appliances with some of the highest magnetic field readings at a six inch distance include hair dryers (as high as 700 milligauss (mG)), microwaves (up to 300 mG), and vacuum cleaners (up to 700 mG). However, the magnetic fields drop off significantly when one increases the distance to the source. Those same high-field appliances have measured fields of 10 mG, 30 mG, and 50 mG at two feet.

Individuals who are concerned about magnetic fields can clearly minimize their exposures by increasing the distance from these appliances when they are operating. Minnesota electrical utilities provide magnetic field measurements in customers' homes to help them to identify the sources and strength of magnetic fields. This type of information can pinpoint specific sources that could be mitigated.

Electric fields are much more easily shielded than are magnetic fields. Thus, electric fields within the home are generally quite low. The most prevalent sources are televisions and computer monitors so minimizing the amount of time being near them and turning them off when not in use will reduce the average electric field exposure.

For more information about EMF health effects research, refer to the web sites on page 25.

CHAPTER 6: CONCLUSIONS AND POLICY RECOMMENDATIONS

Conclusions

Some epidemiological results do show a weak but consistent association between childhood leukemia and increasing exposure to EMF (see the conclusions of IARC and NIEHS). However, epidemiological studies alone are considered insufficient for concluding that a cause and effect relationship exists, and the association must be supported by data from laboratory studies. Existing laboratory studies have not substantiated this relationship (see NTP, 1999; Takebe et al., 2001), nor have scientists been able to understand the biological mechanism of how EMF could cause adverse effects. In addition, epidemiological studies of various other diseases, in both children and adults, have failed to show any consistent pattern of harm from EMF.

The Minnesota Department of Health concludes that the current body of evidence is insufficient to establish a cause and effect relationship between EMF and adverse health effects. However, as with many other environmental health issues, the possibility of a health risk from EMF cannot be dismissed. Construction of new generation and transmission facilities to meet increasing electrical needs in the State is likely to increase public exposure to EMF. Based on these considerations, the Work Group considers it prudent public health policy to take a prudent avoidance approach to mitigating EMF exposures.

Policy Recommendations: Prudent Avoidance Measures

The uncertainty surrounding EMF health effects presents a difficult context in which to make regulatory decisions. Because adverse health effects resulting from EMF cannot be proven or disproven, the Work Group considers it prudent public health policy to take a prudent avoidance approach. This approach suggests that one should avoid any activity or exposure about which there are questions of safety or health, at least to the extent that the activity can be avoided easily or cheaply. This is similar to the findings of the NIEHS report, which states: ". . .because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures."

Based on this approach, the Work Group developed several policy recommendations that aim to balance protecting public health with the uncertainty surrounding EMF health effects. The recommendations are outlined below. Implementation of the recommendations will ultimately depend on decision-makers' underlying regulatory philosophy.

Apply EMF mitigation options to new or upgraded electric transmission and distribution lines

There are several options for minimizing or avoiding EMF in the construction and operation of new or upgraded transmission and distribution lines, as discussed in Chapter 5. These options should be applied wherever possible in infrastructure construction projects. For example, utilities seeking to site new transmission lines in Minnesota should use low-cost engineering methods to decrease EMF wherever possible. The kinds of avoidance measures that may be considered prudent can only be determined on a case-by-case basis. Each project's technical specifications and performance requirements will define the parameters of the project.

Encourage conservation

Lowering electric consumption ultimately results in reduced need for new and updated generation facilities, transmission lines, and distribution lines, and hence reduces exposure to EMF. Both the Minnesota Public Utilities Commission and the Department of Commerce use various ways to encourage cost-effective conservation, including using financial incentives, encouraging utilities to improve conservation programs under funding required by law, and setting conservation goals. Within the Department of Commerce, the State Energy Office provides direct outreach, through various educational and technical assistance programs, to help Minnesotans save energy. These efforts are intended to result in reduced energy use, lower energy bills for consumers and fewer negative environmental effects of electricity production and transmission. They should continue to be encouraged and supported.

Encourage distributed generation

There is growing interest in generating electricity with small plants at many locations, commonly referred to as distributed generation. Through the use of cogeneration plants (those producing both heat and electricity and located near the load) and small production facilities like microturbines, power can be generated and used in a fairly localized area. Distributed generation can help reduce the need to build new lines or upgrade existing lines through residential neighborhoods.

Continue to monitor EMF research

Future research will continue to shed light on the health effects of EMF. The Minnesota Department of Health should continue to monitor EMF research and put updated information on the MDH Web site, so that the most recent data are available to policy makers and the public.

Encourage utilities to work with customers on household EMF issues

EMF is emitted at various levels of electric power transmission, generation, and end use. While most people associate EMF with power lines, it is also emitted from most household appliances and household wiring. Upon request, most Minnesota electric utilities will conduct magnetic field measurements in customers' homes or businesses at no cost. This information can identify fields that seem particularly strong and may pinpoint specific sources that can be attenuated. When there are concerns about EMF exposures and health risks, customers and utilities are encouraged to evaluate sources and strength of EMF in places where people live and work.

Provide public education

Public education efforts are necessary to inform the public of the state of current scientific knowledge. The nature, multiple sources, and potential risks associated with electric and magnetic fields, the range of fields one may experience in daily life, and the simple measures one may take to reduce exposures (e.g., distancing oneself from sources of the fields) are probably not common knowledge among the general public. Public education efforts would help support rational dialogue and involvement of stakeholders in EMF discussions, and help people minimize EMF exposure in their home and work environments.

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APPENDIX: EMF POLICIES AND ACTIVITIES IN OTHER STATES

Exposure Standards

Currently there are no federal or state health-based exposure standards for magnetic fields. This is due to the fact that there is insufficient scientific evidence at this time to develop a health-based standard.

Some states have established maximum limits for electric and/or magnetic fields (see table below). The states that have established magnetic field standards did not base them on human or environmental impacts, but merely established the levels found on existing lines as the maximum values for new lines. There are no Federal standards for magnetic fields. For power line permitting purposes, the Minnesota Environmental Quality Board has restricted, on a project-by-project basis, the maximum level for electric fields to 8 kilovolts per meter (kV/m), as measured one meter above ground level.

State	Electric Field On ROW	Electric Field Edge, ROW	Magnetic Field Edge, ROW
Florida	8 kV/m[a] 10Kv/m[b]	2 kV/m	150 mG[a] (max load) 200 mG[b] (max load) 250 mG[c] (max load)
Minnesota	8 kV/m		
Montana	7 kV/m[d]	1 kV/m	
New Jersey		3 kV/m	
New York	11.8 kV/m 11 kV/m[c] 7 kV/m[d]	1.6 kV/m	200 mG (max load)
Oregon	9 kV/m		

a-for lines of 69-230 kV
b-for 500 kV lines
c-for 500 kV lines on certain existing ROW
d-maximum for highway crossings
d-maximum for private road crossings
Key: ROW = right of way; mG = milligauss; kV/m = kilovolts per meter

Source: *Questions and Answers About EMF*. National Institute of Environmental Health Sciences and U.S. Department of Energy, 1995.

Other EMF Policies and Activities

A number of states have developed policies with regard to electric and magnetic fields. These policies usually are of two types: those that identify the agency responsible for approving new electrical facilities and lines, and those that request regular review of new EMF research. Of those states that have an established policy, most established the policy 5 to 10 years ago and are not actively engaged in developing new policy. Only one state, California, has been actively engaged in sponsoring research and developing policies that go beyond the two types described above.

California

In 1993 the California Public Utilities Commission mandated that the California Department of Health Services (CDHS) oversee a program of research and policy analysis about power frequency EMFs. CDHS created the California EMF Program which sponsored projects on EMF exposures in schools and the workplace; research on EMF and miscarriages; and analyses of EMF policy options.

In 2001 the California EMF Program released a *draft* Risk Evaluation report (CDHS 2001). This report summarized the conclusions of three CDHS reviewers regarding possible associations between EMFs and 13 health conditions. The Program also produced fact sheets and other documents which are available on the CDHS web site (see link below).

While some scientists praised the California reviewers for using a novel approach to conduct their Risk Evaluation, several other researchers raised concerns regarding their report's conclusions, and more fundamentally, the process used to conduct the evaluation (CDHS 2002). MDH reviewed the report and public comments, and has concluded that there is no scientific consensus at this time on the report's conclusions, including the degrees of confidence that the reviewers assigned regarding a causal relationship between EMF and adverse health effects. MDH also has concluded that there are significant limitations in California's evaluation, including the failure to adequately address the lack of supporting data from animal laboratory studies and the lack of a plausible biological mechanism of how EMF causes harm.

The California EMF Program is expected to complete a revised Risk Evaluation report in June 2002. The overall Program is expected to conclude in 2002. At this time, it is not clear how the conclusions of the Risk Evaluation and policy analyses will be used by California decision-makers. MDH will continue to track EMF developments in California and other states. (For more information about the California EMF Program, see the CDHS site: http://www.dhs.ca.gov/ps/deodc/ehib/emf/).

Florida

The Transmission Line Siting Act of Florida requires certification (licensing) of electrical transmission lines which are 230 kV or larger and which cross a county line and are 15 miles or more in length. There are exceptions if certain rights-of-way are used.

Certification is an umbrella permit for all affected state, regional and local agencies, and includes any regulatory activity that would be applicable under these agency regulations for the facility. The Department of Environmental Protection is the lead agency responsible for coordinating the interagency review and certification (licensing). The Siting Coordination Office, in conjunction with the Office of General Counsel, has been assigned by the Department to perform the administrative and legal tasks of the certification process. However, the actual licensing entity under the statutes is the Siting Board (governor and cabinet), not the Department or the other lead agencies.

In 1989, the Environmental Regulation Commission (ERC) adopted a rule limiting EMF from electrical transmission lines and substations. Due to the lack of scientific evidence that exposure to power line EMF would produce adverse health effects, the ERC based the field strength standards on the premise that new transmission lines and substations should not produce fields greater than the EMF from existing lines.

The ERC also required the Department of Environmental Protection to monitor EMF scientific research and to submit annual reports on the findings. The most recent report on EMF research (2001) concluded with the following statement:

> We seem to be approaching a time when some aspects of EMF exposure may be deemed a slight risk, but we are still lacking knowledge of EMF impact mechanisms and adequate scientific proof to allow a valid estimate of risk to the public and the knowledge to set a regulatory standard to manage the risk. We therefore do not recommend any change in the current EMF Rule.

Maryland

The Power Plant Research Program (PPRP) is responsible for managing a consolidated review of all issues related to power generation in Maryland. This provides a framework for the comprehensive review of all electric power issues with the goal of balancing need, cost, and impacts. The PPRP was established in 1971 and is supported by an Environmental Trust Fund; funding is provided through an environmental surcharge that is assessed on all electricity used in the State.

Electric power generators must obtain a Certificate of Public Convenience and Necessity from the Maryland Public Service Commission to build or modify power plants and transmission lines in the State. As part of the review, PPRP analyzes the need, consolidates issue analysis from several agencies, and evaluates potential environmental impacts.

PPRP's ongoing assessments involve plant-specific studies and more general monitoring, research and modeling projects. These projects cover a spectrum of issues, such as environmental impact assessments, technology evaluations and demonstrations, and economic studies. One of the projects is tracking the research on potential human health effects associated with electric and magnetic fields.

The most recent report from the PPRP (October 2001) reviewed the EMF health risk assessments current at that time and reached the following conclusion:

> None of the assessments determined EMF to be a confirmed cause of human cancer, instead calling EMF a possible human carcinogen, based on the epidemiological evidence. The lack of complementary confirmatory evidence from animal and other laboratory studies bears on the distinction between a known vs. probable vs. possible carcinogen classification. All assessments commented on the uncertainties in determining causality, particularly because causative exposure and dose characteristics had not yet been clearly identified from the research. In summary, EMF exposures remain suspect but remaining unknowns are the reason for continued lack of firm clear affirmation of health risks from EMF exposure.

For more information about EMF-related activities and publications in Maryland, contact PPRP by phone at 410-260-8660 or visit the PPRP web site: http://www.dnr.state.md.us/bay/pprp/.

New Jersey

The New Jersey Department of Environmental Protection has a Radiation Protection Program that includes a Non-ionizing Radiation Section (NRS). The NRS provides information to the public concerning radio frequency and electromagnetic fields through distribution of U.S. Environmental Protection Agency, Federal Communications Commission, and U.S. Department of Energy documents. With regard to magnetic fields the NRS currently states on their web site:

> It is not known at this point whether exposure to magnetic fields from power frequency sources constitutes a health hazard. Therefore, it cannot be determined what levels of exposure are "safe" or "unsafe." Some studies have shown that exposure to higher levels of this radiation is not necessarily worse than exposure to lower levels. More research is required to identify dose-response relationships. There is some evidence from laboratory studies to suggest that there may be "windows" for effects. This means that biological effects are observed at some frequencies and intensities but not at others. Also, it is not known if continuous exposure to a given field intensity causes a biological effect, or if repeatedly entering and exiting of the field causes effects. In light of all this uncertainty, it is impossible to say what is a "safe" distance from any magnetic field source or what is a "safe" exposure.

For more information about New Jersey's EMF-related activities, refer to the New Jersey Department of Environmental Protection web site: http://www.state.nj.us/dep/rpp/nrs/index.htm.

New York

The Department of Public Service has a broad mandate to ensure that all New Yorkers have access to reliable and low-cost utility services. The Department is the staff arm of the Public Service Commission, which regulates the state's utilities and has jurisdiction over the siting of major gas and electric transmission facilities. Within the Department, the Office of Electricity and Environment coordinates review of applications for new power plants and major transmission lines, and monitors the construction of such facilities to ensure compliance with technical and environmental requirements.

In 1991, the Public Service Commission established an interim measure that requires new high voltage transmission lines in New York to be designed so that the maximum magnetic fields at the edge of the right-of-way will not exceed the maximum magnetic field levels produced by the average of 345 kV lines now in operation. This interim magnetic field standard of 200 milligauss, at one meter above the ground at the edge of the right-of-way, applies when the line is operating at its highest continuous current rating.

The New York Department of Health has issued the following response to the question of what is a safe level of magnetic field:

> There is no number to which we can point and say, "that is a safe or dangerous level of EMF exposure." We don't know if EMF exposure is harmful. We don't know if certain levels of EMFs are safer or less safe than other exposures. We do not know if continuous exposure to a given field intensity causes a biological effect, or if rapid changes in exposures cause effects.

Utah

The Radiation Control Board (RCB) guides development of radiation control policy and rules in the state. Members are appointed by the Utah governor with the consent of the Utah Senate. In December 1993 the Utah Radiation Control Board adopted a position statement on health effects from Extremely Low Frequency Electromagnetic Fields:

> . . .while there may be indications for further biomedical research on this question, the existing scientific evidence is not sufficient to warrant legislation or regulation at this time.
>
> The Board strongly recommends, however, that the Division of Radiation Control (DRC) establish an efficient program to monitor reputable scientific literature dealing with the biomedical effects of ELF/EMF. Further, the DRC should notify the Board <u>immediately</u> whenever reviewers believe that significant new scientific evidence has been published.

No further action regarding EMF has been taken by the RCB.

Virginia

The State Corporation Commission (SCC) is vested with regulatory authority over many business and economic interests in Virginia. One of its major responsibilities is to consider the environmental impact of certain electric generating and transmission facilities proposed for construction in Virginia by regulated utilities.

The Division of Energy Regulation assists the SCC's three commissioners in regulating Virginia's utilities. Its responsibilities include monitoring utility construction projects and reviewing applications for construction of transmission lines exceeding 150 kilovolts and electric generating units exceeding 100 megawatts.

In May 2001 the SCC approved a 57-mile, 765 kV transmission line proposed by American Electric Power (AEP). While the SCC does not have a formal policy on EMF, AEP offered to purchase any home that is within 100 feet of the edge of the right-of-way, which is 200 feet.

In October 2000, the Virginia Department of Health, in cooperation with the SCC, prepared the report "Monitoring of Ongoing Research on Health Effects of High Voltage Transmission Lines." The report concluded that:

> There is no conclusive and convincing evidence that exposure to extremely low frequency EMF emanated from nearby high voltage transmission lines is causally associated with an increased incidence of cancer or other detrimental health effects in humans.

For a copy of the October 2000 report, see the Virginia Department of Health web site: http://www.vdh.state.va.us/HHControl/highfinal.PDF.

Wisconsin

The Public Service Commission of Wisconsin (PSC) is an independent regulatory agency responsible for the regulation of Wisconsin public utilities, including those that are municipally owned. The Electric Division is responsible for all major aspects of the PSC regulation of electric utilities. Utilities need PSC approval for their rates, and for building large power plants or power lines.

A utility must get approval from the Commission to build an electric transmission line if:

- The proposed line is 230 kilovolts (kV) or more;
- The proposed line is 100 kV or more, is over one mile in length, and needs new right-of-way (ROW); or
- The proposed line's cost will be above a certain percent of the utility's annual revenue.

The Commission decides whether a power line can be built, how it should be designed, and where it must be located.

Since 1989, the Commission has periodically reviewed the science on EMF and has held hearings to consider the topic of EMF and human health effects. The most recent hearings on EMF were held in July 1998. As a result of these hearings, the Commission has ordered Wisconsin utilities to enact several measures, including contributing to the national research effort and providing measurements and information to the public on EMF.

The Commission recently updated its information brochure (22 pages) entitled “PSC Overview Series… EMF – Electric & Magnetic Fields.” The summary paragraphs are as follows:

> Many scientists believe the potential for health risks for exposure to EMF is very small. This is supported, in part, by weak epidemiological evidence and the lack of a plausible biological mechanism that explains how exposure to EMF could cause disease. The magnetic fields produced by electricity are weak and do not have enough energy to break chemical bonds or to cause mutations in DNA. Without a mechanism, scientists have no idea what kind of exposure, if any, might be harmful. In addition, whole animal studies investigating long-term exposure to power-frequency EMF have shown no connection between exposure and cancer of any kind.
>
> While scientific consensus appears to be forming, there are still some unanswered questions about EMF exposure and human health. The Commission will continue to consider EMF in its power line siting decisions. But the Commission must balance the likelihood of health effects from exposure to power line EMF with issues of need, cost, and environmental impact. The PSC will base its EMF policy on a continuing review of scientific research.

For more about the EMF overview fact sheet prepared by the Wisconsin PSC, see the web site: http://www.psc.state.wi.us/pdffiles/brochures/emf.pdf.