POLICY OPTIONS IN THE FACE OF POSSIBLE RISK FROM POWER FREQUENCY ELECTRIC AND MAGNETIC FIELDS (EMF)

California
EMF
Program

1515 Clay Street, 17th Floor
Oakland, CA 94612
(510) 622-4500 phone
(510) 622-4505 fax

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Gray Davis
Governor
State of California

Grantland Johnson
Secretary
Health and Human Services Agency

Diana M. Bontá, R.N., Dr.P.H.
Director
Department of Health Services

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ABSTRACT

In 1993, the California Public Utilities Commission (CPUC) mandated that the Department of Health Services (DHS) oversee a program of research and policy analysis about power frequency EMFs (see www.dhs.ca.gov/ehib/emf). In addition to projects on EMF exposures in schools and the workplace, and a study on EMFs and miscarriage, the program supported two policy analyses. They dealt respectively with possible EMF information campaigns and avoidance measures, on the power grid and in schools.

A stakeholder's advisory group oversaw the EMF Program. In overseeing the policy analysis it became clear that stakeholders operate under four different policy frameworks that lead to differences in preferred action with regard to involuntary environmental exposures. Economists and regulators adhere to a "utilitarian" framework that aims at "the most good for the most people at the least cost." Many citizens adhere to a "social justice" framework that aims at "protecting the most vulnerable regardless of cost." Others adhere to a "virtual-certainty-required" framework that requires certainty of a problem before acting on it. Still others adhere to a "non-interventionist" framework that prefers voluntary non-governmental approaches to environmental risk regardless of the degree of confidence that there is a problem.

To assist economists and regulators who frame policy in terms of costs and benefits the policy analysts asked, "how confident must one be that EMFs cause disease and how much disease must be caused before one could justify implementing cheap or expensive EMF information campaign and/or avoidance measures?" The results suggest that a range of expenditures, from inexpensive to expensive, could be justified from a cost-benefit perspective even without 100% confidence that EMFs cause disease. Depending on the avoidance measures taken this could increase 1999 utility rates between 0.2% to 3.5% for a decade and could cost $0.48 to $7.6 billion. Information campaigns would be much less expensive. Judging by other protective measures taken, economists have determined that society seems willing to pay around $5 million per statistical death avoided. To make these investments costs beneficial, economists would require avoiding between 100 and 1,500 deaths over the 35-year useful life of the modified power lines statewide. (The DHS contractor acknowledges uncertainty in costs and the means of financing projects; thus these numbers could be higher by a factor of 2.)

School EMF interventions could cost $40-$50 million statewide. Therefore to make this investment cost beneficial, economists would require avoiding ten deaths among the five million students and half a million staff over the assumed 35-year useful life of the modified schools statewide.

For those who use a "social justice" policy framework that aims at protecting the vulnerable regardless of cost, the analyses discuss issues of interest to that perspective. For those who use a "virtual-certainty-required" framework that requires certainty of an EMF effect to take any action, the analyses and the risk evaluation (see below) provides them with the information they need to take a position. Adherents to the "non-interventionist" framework will find discussions of voluntary or informational strategies that could be taken.

Adherents to the "utilitarian," "social justice," and "virtual-certainty-required" policy frameworks will probably advocate different courses of action on the basis of these assessments and analyses. The CPUC has administrative procedures to resolve such differences with regard to power grid policy. They can use the information that the California EMF Program has gathered with regard to the power grid in any such deliberations. The state agencies and local districts concerned with educational facilities can use the policy analysis and exposure information in any policy activities that they pursue. DHS will not be making any recommendations on policy at this point in the process.

THE CALIFORNIA EMF PROGRAM

In 1993, the CPUC directed investor-owned utilities to provide funds for policy relevant research and public education. Municipal utilities also contributed to this $7 million program. The resulting California EMF Program was fiscally implemented by the nonprofit Public Health Institute (PHI) and directed by DHS. At the request of the CPUC, a stakeholder's group including concerned citizens, the International Brotherhood of Electrical Workers, utilities, and various public interest groups advised DHS on the research topics to pursue and provided detailed comments on two policy projects. These and other projects supported by the EMF Program are described on the project website (www.dhs.ca.gov/ehib/emf).

Stakeholders asked DHS to carry out a risk evaluation in a way that would be helpful for forming policy in the face of uncertainty. A Science Advisory Panel of scientists without conflict of interest or particular biases about the EMF issue provided external criticism of the Risk Evaluation.

At the same time, in 1993, the CPUC directed investor-owned utilities to follow a "no and low cost" EMF avoidance policy in constructing new transmission and distribution lines, allowing them to charge rate payers for up to 4% of the total project cost for avoiding EMFs. They also directed the utilities to provide yearly updates on EMF research in one monthly bill per year and to provide free EMF measurements to their customers.

FOUR POLICY FRAMEWORKS LEAD TO DIFFERENT COURSES OF ACTION UNDER UNCERTAINTY

Members of the scientific community are far from unanimous in their degree of confidence that EMFs influence the risk of various diseases. Making policy in the face of uncertainty is characteristic of many public health issues. Examples include global warming, mad-cow disease, and irradiated foods. In the course of designing and critiquing the Program's school and power grid policy projects, it became clear that stakeholders have different policy frameworks that they use in approaching such problems involving voluntary and involuntary exposures. It also became clear that many arguments about policy choices are really arguments about frameworks. Economists, engineers, and regulatory agencies often use a predominantly results-oriented "utilitarian" framework. Any given stakeholder using this framework considers his/her options along a number of criteria and chooses the option that produces the best trade-offs between the various criteria. In order to find the option with the best balance of criteria, the utilitarian stakeholder may assign dollar values to tangible criteria such as project costs and even to criteria such as aesthetic consequences or quality-adjusted years of human lives saved. When stakeholders using this approach end up advocating different courses of action because they have different interests, the utilitarian resolves the conflict by choosing the solution that aims at producing the "most good for the most people at the least cost." Sometimes this ignores the interests of some small segment of society. On many issues, members of the general public do not adhere to the utilitarian framework. Often they adhere either to a "social justice" framework that tries to fulfill duties or protect rights of the vulnerable regardless of cost, a "non-interference" framework that tries to protect individual and property rights from governmental interference, or a framework that requires virtual certainty of a problem before taking action. Adherents to these frameworks might prefer different policy options. For example, suppose a municipality that owned its own electrical utility decided that it was probable that magnetic fields from power lines and appliances were hazardous and wanted to do something about it. The utilitarians in town might recommend that the municipal utility should pay for the most cost-effective measures to reduce exposure, even if not deriving from the sources for which they were responsible. For example, they could buy up enough old, high-exposure electric blankets and replace them with new, low-exposure models, to prevent as much disease that might be caused by the power grid. The adherents to the social justice framework might point out that the minority of people living next to the power grid were still at unequal risk. They might invoke a strong form of the "precautionary principle" that expensive avoidance policies are warranted on the basis of a few credible scientists suspecting a small risk that violates the rights of even a small group of people. They might say that following the precepts of environmental justice, there was a special duty to protect this group if it had been unfairly singled out for EMF exposure on the basis of previous exposures to other hazards, low-income levels, less access to medical care, or racial inequalities. From this perspective environmental agents like EMFs should be treated as "guilty until proven innocent." Therefore, this framework would propose that the people living near the power lines should be protected by modifying the lines to lower fields even if it were more expensive to do so. They might also invoke a duty of the utilities "to clean up their own mess" at the utility's expense. The adherents to "non-interference" might oppose both options because they involved involuntarily taxing the many for the benefit of the few. Regardless of the degree of confidence in the existence of an EMF hazard, they might prefer a "right to know" information program to allow the free market and voluntary actions of those who were concerned to solve the problem. Adherents to the "virtual-certainty-required" framework would not want to take any action unless all scientists in the field were totally convinced of a problem. For these adherents, EMFs are "innocent until proven guilty." There is no technical resolution to these kinds of arguments. A democracy handles them through the political process.

Policy contractors to the California EMF Program were instructed to use an approach that would be useful to adherents of all frameworks and to highlight issues where the different policy frameworks might clash so that decision-makers could be helped to anticipate how features of different policy options might be attractive to stakeholders who adhered predominantly to one or the other policy frameworks. The "social justice," "non-interference," and "virtual-certainty required" frameworks are governed by fairly straightforward prescriptive principles and do not require extensive presentations. Their arguments are easier for most stakeholders to grasp. The results-oriented "utilitarian" analysis, by its nature,

requires extensive discussion of the potential consequences and costs of each option under consideration. Because of this, to be responsive to the utilitarian stakeholders and regulators, the bulk of the analyses are utilitarian and may be difficult for many stakeholders to follow. It is not the role of DHS at this point in the process to advocate for any one of these four policy frameworks, although DHS has meaningfully involved all stakeholders from the very beginning of the California EMF Program. This is of particular concern to the social justice/environmental justice frameworks

In forming policy about the ubiquitous exposures from electricity, policymakers need to decide ahead of time if they will be considering issues of cost and if they would take action based on any degree of confidence about an EMF hazard less than 100%. For those who ignore costs or only act if there is virtual certainty of a hazard, substantial parts of the policy projects supported by the California EMF Program will not be helpful. For those who do consider these issues, the policy analysis should be helpful.

The decision analysis approaches used in the policy projects accommodates the non-utilitarian policy frameworks to the extent that they allow stakeholders to keep track of and take account of who pays for avoidance and who receives the unusual exposures. It also deals explicitly with uncertainties.

THE ECONOMISTS APPROACH TO THE VALUE OF PUBLIC HEALTH ACTION

Asking about the dollar value of a statistical life, as economists do, only makes sense from the utilitarian policy framework, which is willing to put dollar values on various criteria like human lives. Since many important stakeholders use this framework we address it head on, although stakeholders who use the social justice framework would feel uncomfortable even asking the question and stakeholders using the virtual-certainty-required framework would be uncomfortable being asked to pay even for inexpensive measures that are warranted by degrees of confidence short of 100%.

The program's policy contractors reviewed the economic (utilitarian) literature that compares various medical, public health, and environmental policies and their efficacy to infer what economists think that society is willing to pay to avoid a statistical death. This varies from program to program, ranging from $1 million to $10 million per death avoided.

As a rough indicator of the health benefit that would be needed by the utilitarian framework to justify the cost of various avoidance measures, economists would divide the unit project cost (e.g., the per mile cost of undergrounding a 69 kV line) by say, $5 million per death avoided. This derives the deaths that an economist would require to be avoided per mile to make the unit project cost "cost-beneficial." We present the "unfinanced" base case project cost numbers of our policy contractors. The reports themselves discuss stakeholder arguments about these and other factual matters. (The figures could easily be higher by a factor of 2.) We also present the statewide project costs both as whole numbers and, for the power grid discussion, as fractions of the statewide utility revenues prior to the 2000/2001 California energy crisis.

In the detailed analyses of the policy projects, the total life cycle costs were considered, including maintenance costs, relative reliability, power losses due to resistance, property value impacts, etc. With the exception of property values, which are discussed later, the general conclusions of the complicated analyses are similar to those presented below considering only the capital costs. Some economists would suggest that the stream of deaths over time that might occur from EMF exposure be discounted to reflect the fact that some would do more to avoid an imminent death than they would to avoid a death 35 years in the future. To make the calculations transparent and because some oppose discounting statistical deaths, we have presented (the smaller) undiscounted numbers. These issues are discussed in the reports themselves.

A conscientious utilitarian would ask if there were an even more cost-beneficial use to which scarce resources could be put. For example, if moneys spent on rephasing or undergrounding transmission lines were spent on anti-smoking education, could more benefit be obtained from the same moneys? The policy analysis contractors point out that there are "decision domains" across which money cannot flow. The CPUC is unlikely to authorize the investor-owned utilities to spend ratepayer money on smoker education, so that question is not realistic. It would be legitimate to ask if the utilities would provide more health benefit by spending money to generate electricity with less sulfur and nitrates for acid rain, less CO_2 for global warming or less mercury for environmental contamination. If these were indeed more cost beneficial, and the utilities were committed to devote redirected EMF resources to them, then one might restrict oneself to cost beneficial activities such as the current "no and low cost avoidance in new projects" and information activities, all of which have a lower total cost, and therefore divert less money from other life-saving activities within the decision domain of the CPUC. The California EMF Program is unable to answer the utilitarian framework questions comparing EMF avoidance with other possible health promoting policies of the utilities since comparable cost benefit analyses of these other issues have not been done. In any case, the non-utilitarian policy

frameworks might use different principles to judge the relative usefulness of EMF avoidance versus avoiding these other problems.

The numbers presented below allow the reader to determine the number of people "exposed" in the state and whether or not the avoidance measures require an implausibly large health benefit to warrant their adoption under the economist's utilitarian cost/benefit framework.

THE POWER GRID

Transmission lines are the high-voltage, high-current lines that run (usually on metal towers) from generators to substations and from substation to substation. There are about 1,700 "corridor" miles of 69 kV to 230 kV transmission lines that run through California residential areas with about 1.5 million people living within 500 feet on either side of these lines and 510,000 individuals living close enough to these lines to be substantially exposed to their magnetic fields (time weighted average {TWA} greater than 2 mG). A milliGauss (mG) is a unit of magnetic field exposure. A typical residence would convey an average exposure between 0.5 and 1 mG.

The inexpensive measures for retrofit lowering of fields that are sometimes possible on the different voltage transmission lines (reverse phasing, optimum phasing, and split phasing) are varied, but costs average out to about $80,000 a mile. By dividing $80,000 per mile cost by $5 million per death avoided gives 0.016 deaths per mile over the 35-year lifetime of a transmission line (or 27 deaths {undiscounted} along all 1,700 miles). If this "inexpensive" measure ($136 million total) could avoid these deaths, economists would say that it would pay for itself. The impact on utility rates for a decade would be a fraction of a percent.

The expensive measure for lowering fields from transmission lines is to underground the lines and heavily insulate them and place them close together so that the magnetic fields cancel. Placement this close is not feasible in aboveground lines. The cost calculations for undergrounding are shown in Table 1.

There are 160,000 miles of aboveground primary distribution lines in California leading (usually on wooden poles) from substations to customers. About 4% are estimated to be in residential areas and to also produce fields of the sort in the "high" category of epidemiological studies. Thus some 6,700 miles of distribution lines are possible candidates for retrofitting on the basis of EMF exposure. Our contractor estimates that 1 million individuals live close enough to these lines to be substantially exposed by their magnetic fields (TWA greater than 2 mG).

The inexpensive but quite efficacious means of canceling magnetic fields that is sometimes possible with distribution lines is achieved by arranging the wires in a "compact delta" configuration. The results of the calculations for these are also shown in Table 1.

For distribution lines, the expensive measure is to underground them and configure the circuits so that the magnetic fields cancel. See Table 1 for the calculations for this measure.

Phasing, configuring, or undergrounding new transmission or distribution lines are less expensive than retrofitting existing lines. The detailed policy analyses address these options separately.

Perhaps 5% of people live in homes with substantially elevated magnetic fields from neutral current returning to the grid along plumbing rather than the neutral wire. This is calculated to affect 550,00 homes and 1.65 million people to the extent that fields in those homes average above 2 mG.

The measure recommended for lowering this exposure is to insert a non-conductive (usually plastic) segment of pipe to force the current back to the neutral wire. This might cost $200 to $500 per home. See Table 1 for the calculations.

The EMF exposures to the public from generating stations and substations would be negligible except for the transmission and distribution lines that enter and leave them. These other sources have been described above.

As can be seen in Table 1, about 1.51 million Californians receive average EMF residential exposures greater than 2 mG from the power grid and another 1.65 million receive such exposures within their homes from the way neutral currents return to the grid via plumbing instead of the neutral lines. Since there are overlaps between these sources the total exposed is less than the sum of these numbers. Except for selected occupational groups, residential exposures account for most of the daily exposures because most people spend so much time at home during a given 24-hour day. The moderate cost measures of rephasing transmission lines, compacting distribution lines, and modifying plumbing would cost about $0.48 billion statewide, increasing utility rates for a decade by less than 1%. One would need to avoid about 96 (undiscounted) deaths statewide over a 35-year period to make these measures seem cost beneficial to an economist. The expensive measure of undergrounding residential area transmission lines and the undergrounding of distribution lines that produce high EMF exposures along with the modest cost of altering plumbing in houses with neutral return problems would

cost about $7.6 billion and would raise utility rates by about 3.5% for a decade. One would need to avoid about 1,500 (undiscounted) deaths over 35 years to make this measure seem cost beneficial to an economist.

TABLE 1. RESIDENTIAL EMF SOURCES, THE COSTS OF MODERATE AND EXPENSIVE MITIGATION, AND THE REQUIRED DEATHS TO AVOID TO SEEM COST BENEFICIAL FOR ECONOMISTS

EMF SOURCE AND MITIGATION	RESIDENTIAL POPULATION "AFFECTED" TWA>2 MG	AMOUNT¥	MODEST COST MEASURES (REPHASING AND COMPACTING LINES)				EXPENSIVE MEASURES (UNDERGROUNDING)			
			UNIT COST	TOTAL COST	% OF 10 YEAR REVENUE	STATEWIDE DEATHS TO AVOID IN 35 YEARS TO JUSTIFY COSTS [1]	UNIT COST	TOTAL COST	% OF 10 YEAR REVENUE	STATEWIDE DEATHS TO AVOID IN 35 YEARS TO JUSTIFY COSTS [1]
TRANSMISSION	510,000	1,700 miles	$80,000 per mile	$136 million	0.06 %	27	$1.46 million per mile	$2.48 billion	1.13 %	495
DISTRIBUTION	1 million	6,700 miles	$35,000 per mile	$234.5 million	0.11%	47	$750,000 per mile	$5.03 billion	2.3 %	1,005
GROUNDING	1.65 million	550,000 homes	$200 per home	$110 million	0.05%	22	$200 per home	$110 million	0.05 %	22
TOTAL	2.59 million*			$480.5 million	0.22 %	96		$7.61 billion	3.46 %	1,522

¥ The miles of line represent the contractor's best estimate. California utilities explained that a special study would be required to provide exact circuit and corridor miles in residential areas.

[1] By dividing total cost by $5 million per death avoided, a utilitarian would derive the number of avoided deaths required to make a measure cost beneficial

* The total number of exposed people is smaller than the sum of people affected by each source, because of an overlap between sources.

Source: von Winterfeldt, D. Power Grid Project. www.dhs.ca.gov/ehib/emf.

Restricting avoidance measures to new transmission or distribution lines would cost less money overall, have less impact on utility rates, and would divert less money from other activities, while having similar cost effectiveness. It would leave the majority of people involuntarily exposed to the power grid without a program directed at them. Information programs respond to the social justice framework's "right to know," but have uncertain cost effectiveness. A program that cost $500,000 a year would need to save one life statewide every decade to make itself cost beneficial.

SCHOOLS

Table 2 shows similar calculations for the four sources (net currents, electrical panels, distribution lines, transmission lines) that account for 80% of the exposures in California schools according to a survey of 89 randomly selected schools carried out for the California EMF Program. The most common source is the misconnecting of neutral conductors in sub-panels and junction boxes.

This leads to a condition called "net currents." This wiring practice is contrary to the electrical code and can increase the probability of fires. It also produces magnetic fields. It is not very expensive to change, but many schools have at least one classroom affected. Proximity to electrical panels is a rare source that requires dealing with expensive shielding. Distribution lines and transmission lines are much less frequent sources of exposure next to schools and can be dealt with as described above. The program's contractors estimate that the total cost of a statewide program to deal with these four sources in order to eliminate fields above 2 mG would be around $43 million. Some stakeholders argue that one should deduct the $16 million for net currents from the total cost since that should be dealt with to conform with the electrical code in any case. A big element of statewide cost would be the systematic survey of EMF exposure in all 8,000 schools to detect unusual sources. (The row totals are not always the sum of the numbers in the cells because not all schools have all sources.)

The economist would require the avoidance of 9 deaths among the 5 million students and among the half a million teachers and staff over a 35-year period to make the $43 million measures cost beneficial.

The bulk of EMF exposure expressed as "milliGauss-hours" is below 2 mG. Hence, the measures in Table 2 aimed at eliminating exposures above 2 mG only eliminate a fraction of the exposure. There is some epidemiological evidence that risk only begins to accrue above 3-4 mG.

TABLE 2. COSTS OF MEETING A 2-MG STANDARD FOR THE SPATIALLY-AVERAGED MAGNETIC FIELD IN CLASSROOMS. COSTS ARE BEST ESTIMATES, BASED ON UNIT COST ESTIMATES AND EXPOSURE DATA IN ZAFFANELLA AND HOOPER 2000. ACTUAL COSTS MAY DIFFER SIGNIFICANTLY FROM THESE ESTIMATES.

	SOURCE				
	NET CURRENTS ONLY	ELECTRICAL PANELS ONLY	DISTRIBUTION LINES ONLY	TRANSMISSION LINES ONLY	ALL FOUR
COST PER AFFECTED SCHOOL	$5,300	$37,000	$30,000	$65,000	$13,000
NUMBER OF AFFECTED SCHOOLS	~ 3,000	~ 300	~ 300	~ 200	~3,500
STATEWIDE TOTAL COSTS	$16 million	$12 million	$9 million	$13 million	$43 million
STATEWIDE DEATHS TO AVOID TO BE COST BENEFICIAL AT $5 MILLION/DEATH	3.2	2.4	1.8	2.6	9
STATEWIDE COSTS, NOT INCLUDING SURVEY	$8 million	$4 million	$8.3 million	$12.8 million	$33 million
STATEWIDE SURVEY COSTS	$8 million	$8 million	$0.7 million	$0.2 million	$10 million
FRACTION OF STATEWIDE SCHOOL-TIME EMF EXPOSURE ELIMINATED	20%	1%	4%	3%	29%

Source: Florig, K. School Policy Project. www.dhs.ca.gov/ehib/emf

DETAILED DECISION ANALYSIS INSIGHTS

Stakeholders pointed out to the policy analysts that direct project construction costs and potential health benefits were not the only criteria by which to compare the status quo to the inexpensive options and the expensive options. Particularly with regard to the all important power grid, stakeholders argued about how the several options would impact reliability, loss of power due to resistance, and property values. It also became clear that the way any changes were financed (pay as you go vs. borrow and pay interest) was important. Another 20 considerations, including tree-cover, avoided pole collisions, impact on air pollution, and electrical fires, were considered but turned out to involve far less costs than the above-listed items. Thus considering these items did not affect the ranking of options. A report and computer models were prepared for distribution lines and various voltage classes of transmission lines, as well as for changing the grounding system to avoid ground currents. These models allowed consultants for the various stakeholders to challenge assumptions made and satisfy themselves that the insights gained were valid. A similar approach was used for the School Policy Analysis.

One contentious issue related to the impact of EMF fears on the value of properties near power lines. Concerned citizen stakeholders argued that EMF fears had already impacted property values and that undergrounding lines would restore adjacent properties to their original values. They argued further that a fairly small property revaluation would cancel out undergrounding costs. For example, if there were one hundred $300,000 homes adjacent to a one-mile-long transmission line they would argue that a 10% revaluation would yield $3 million for undergrounding. The policy analyst contractors pointed out that people buy and sell houses frequently in California so that undergrounding a power line might restore original value to some owners who had bought prior to the initiation of EMF fears in the

1980s, but would constitute a windfall for those who might have bought cheaply after the fears began. Furthermore, unless the power line neighbors managed to spread the cost of property losses to all rate payers, the fact that they received restitutions or windfalls would not affect the burden on utility rates for the rest of the rate payers. Counting property values losses due to EMF fears would also set a precedent for other environmental agents of potential but uncertain risks. Also, not all power line neighbors own their dwellings, thus issues of environmental justice come into play. Finally, a special subproject of the power grid policy analysis suggested that it would be very costly and extremely difficult to provide solid evidence as to the amount of property impact due to EMFs as opposed to aesthetic considerations. This will be an important policy issue for the CPUC.

The reader should refer to the summaries and full reports of the actual projects for the full set of conclusions (www.dhs.ca.gov/ehib/emf). In general, both the power grid and the school policy analyses concluded that there were inexpensive to moderately expensive measures that could be justified on a cost-benefit basis if there were a moderate degree of confidence that childhood leukemia alone was affected by EMFs. Expensive measures would not be justified even by a 100% degree of confidence of a quite strong effect on this disease alone, although a moderate degree of confidence that EMFs contributed to the cause of several diseases would warrant expensive measures.

Both policy analyses examined the option of setting standards for areas near power lines and in schools. This is a more demanding approach than simply doing the best one can by requiring the use of available technology to lower fields to the degree possible. The rationale for setting a particular number requires confidence that the relevant metric is known and that a safe level can be defined. With ionizing radiation where no threshold of effect is assumed, some "de minimis" risk level is chosen, usually a level of exposure corresponding to a 1/ million or 1/100 thousand risk. For other agents with thresholds of effect some safety factors ranging from 10 to 1000 fold have been used. Using that approach, if x milliGauss was the lowest level at which one shows signs of a health effect, the standard would be set at x/1000 milliGauss. Any of these approaches would lead to requiring levels far below background levels in homes far from power lines. The pros and cons of standards are discussed in each of the policy analyses.

Three scientists were assigned by DHS to review the EMF literature, a physician/epidemiologist, a geneticist/epidemiologist, and a physicist with training in epidemiology. They were assisted by ten other DHS scientists. The reader can see from the Risk Evaluation (www.dhs.ca.gov/ehib/emf) that, prior to considering the specific evidence about EMFs, the scientists started with a low degree of confidence that every day exposures to EMFs would cause disease. After reviewing the EMF evidence this degree of confidence increased. To one degree or another all three of the DHS scientists leaned toward the belief that EMFs can cause some amount of increased risk of childhood leukemia, adult brain cancer, Lou Gehrig's Disease, and miscarriage. On the other hand, they strongly believed that EMFs do not increase the risk of birth defects or low birth weight, and strongly believed that EMFs are not "universal carcinogens" since not all the cancer types studied were associated with EMFs. To one degree or another they leaned away from believing that EMFs cause an increased risk of heart disease, Alzheimer's Disease, Depression, or symptoms attributed by some to sensitivity to EMFs. All three scientists had judgments that were close to being evenly divided between the belief that EMFs do or do not cause some degree of increased risk of suicide. For adult leukemia two of the scientists were close to the dividing line between believing or not believing and one was prone to believe that EMFs caused some degree of increased risk. While there are important differences between the three DHS reviewers' conclusions, the DHS scientists are more inclined to believe that EMF exposure increased the risk of the above health problems than were the majority of the members of scientific committees convened by the National Institutes of Environmental Health working group (NIEHS) in 1998, by the International Agency for Research on Cancer (IARC) in 2001, and by the British National Radiation Protection Board (NRPB) in 2001 to evaluate the scientific literature. These other committees all assessed EMFs as a "possible" carcinogen for childhood leukemia. Thus, like the DHS panel, these other three panels were not much swayed by theoretical arguments of physicists that residential EMFs were so weak as to make any biological effect impossible. NIEHS additionally assessed EMFs as a possible carcinogen for adult lymphoid leukemia and NRPB assessed a possible link with Lou Gehrig's Disease. The three DHS scientists differed in that they had a somewhat higher degree of belief that EMF is linked with these three diseases and gave credence to evidence of a link to adult brain cancer and miscarriage that the other panels either didn't consider or characterized as "inadequate." There are several reasons for these differences. The three DHS scientists thought there were reasons why animal and test tube experiments might have failed to pick up a mechanism or a health problem; hence, the absence of much support from such animal and test tube studies did not reduce their confidence much or lead them to strongly distrust epidemiological evidence from statistical studies in human populations.

Since even the lowest risks detectable by epidemiologists imply lifetime risks greater than 1 per 100,000, even the associations with the rarest diseases could be of regulatory interest if real. Nonetheless, the absolute individual risks of EMF exposure would be such that the vast majority of highly exposed people would not contract these diseases. Even if only a few percent of the background California

deaths from conditions that received some degree of credibility from the DHS scientists (childhood leukemia {3,465 background deaths/35 years}, adult brain cancer {45,290 background deaths/35year}, Lou Gehrig's disease {15,190 background deaths/35 years}) this could be sufficient to exceed the 98 deaths over 35 years needed to make modest changes to the power grid cost beneficial over a 35 year period. The same could be said for the 9 deaths over 35 years that would be required to make changes in schools cost beneficial.

A variety of electrical phenomena are present in the vicinity of power lines, in-home wiring, plumbing, and appliances. These include electric and magnetic fields with a variety of frequencies and orientations, stray currents from contact with grounded plumbing, and air pollution particles charged by electric fields. The epidemiological studies primarily implicate the magnetic fields or something closely correlated with them. Some researchers think that associated high or low frequency stray contact currents or charged air pollution particles are the true explanation rather than magnetic fields. The actions one would take to eliminate the fields are not always the same as one would take to eliminate the currents or the charged particles. There are some situations where different costly measures would be required to address the above-mentioned three possible explanations. There are other situations where one or more inexpensive avoidance actions will address all three. This additional uncertainty about what aspect of the mixture might need to be mitigated will thus provide a challenge for policymakers. The California EMF Program funded policy projects to explore various options that could be pursued in the face of these uncertainties (see www.dhs.ca.gov/ehib/emf). These are available to guide the CPUC and other state agencies in policy formation.

OTHER POLICY IMPLICATIONS

The DHS is not making recommendations at this point in the process. The interested public should be referred to the power grid and school policy analysis projects, which deal with various topics. These include inexpensive or expensive avoidance measures on the power grid and in schools and the cost effectiveness of further research. The program also funded a study on the feasibility of identifying tasks such as using power tools that were likely to convey EMF exposure. This project is of potential usefulness to those concerned about occupational policy, such as the California Department of Industrial Relations.

The policy projects do not deal with all the issues that might be of interest to the public. Some of these include:

?? Continuing or not continuing the CPUC policy of no- and low-cost avoidance in new projects, providing yearly information notices on EMFs in electricity bills and free EMF measurements for customers

?? Whether or not to permit leasing rights of way-under transmission lines, to permit the siting of playgrounds and jogging paths near transmission lines, to allow the changing of amperage on existing transmission towers, or requiring the logging of currents on transmission lines to facilitate further study

?? Whether or not to train and certify those who might test schools for EMFs or do electrical contracting work there

?? Options for other types of buildings, such as office buildings, hospitals , daycare centers, nursing homes, factories

?? Options and public information about EMFs in electrical rail transit and electrical or hybrid automobiles

?? Options for electrical and other occupations

?? Options for providing education and technical assistance to government agencies and the public

?? Options for the design of appliances or for building codes

?? Options for EMF avoidance in occupational settings

?? The role (if any) of conservation and of solar and wind power and "distributed generation" in reducing the amount of electricity used and the distance it must travel

?? The oversight, organization and funding of any further research, as well as topics for further policy relevant research (if any) such as studies of the relative reliability of above-ground and below-ground power lines, the occurrence of electrocutions along the power grid, and further studies of common health conditions possibly associated with EMFs

?? Options for implementing any actions so that they are or are not sensitive to fairness and issues of environmental justice

From the utilitarian cost-benefit perspective, the degree of confidence about causality for the various diseases considered would suggest that a number of inexpensive and moderate cost measures could be justified for adoption.

On the basis of the Risk Evaluation, adherents to the various policy frameworks may advocate different courses of action. Adherents to the social justice framework may well advocate more expensive or wide-reaching measures. Adherents to the virtual-certainty-required framework may advocate no action at this time, while adherents of the non-interference framework may advocate informational approaches only.

The CPUC has administrative procedures for reconciling conflicting interests and perspectives with regard to the power grid. This is particularly important in the face of the need in California for more capacity in generation and transmission of electricity. State and local agencies develop policy for schools. Since electricity is so ubiquitous many agencies have potential interest in this issue.

RISK COMMUNICATION AND IMPLICATIONS FOR OTHER EMF DECISIONS

The Program paid for a detailed analysis related to the power grid and to public schools, but electricity is everywhere and central to society in developed countries. By taking any action with regard to the power grid and or schools, policymakers would send a message about the need to make changes in the design of appliances, commercial and public buildings, electrical transportation, and workplace standards. While the Risk Assessment shows that the vast majority of individuals would not be affected by EMFs, there could well be anxiety generated by mandated avoidance action in the school, power grid, and home grounding sectors. Anxiety itself has health consequences. There is also the possibility of tort lawsuits in the various sectors where electricity is used and EMF exposure occurs. These legitimate concerns are raised when any new environmental regulation is proposed. For example, there were major concerns raised about such issues when Proposition 65 was adopted in the mid-1980s requiring the labeling of products that contained recognized carcinogens and reproductive toxicants. Now, more than a decade later, many of the original fears about the regulation are seen to have been exaggerated. Experience has shown that people tend to take a “better safe than sorry” approach to even very small risks, if there is no benefit to them personally and the exposure is involuntary. However, people will often tolerate risks and not be anxious if there is cost to them in removing the exposure or if there is a benefit from tolerating it. Therefore, it will be important to provide information to the public and to develop stakeholder agreement on how to proceed with regard to EMF exposures.