21.0 CONCLUSIONS

21.1 OVERALL CONCLUSIONS

Having examined and discussed each of the health endpoints mentioned above in a separate chapter in the main document, the three DHS reviewers each assigned their best judgment IARC classification and degree of certainty (as a number between 0 and 100). These determinations are summarized in Table 21.1. Column 1 displays the condition considered. Column 2 identifies the reviewer. Column 3 shows the IARC classification in which the number "1" denotes a definite hazard: "2a" a probable hazard, "2b" a possible hazard, and "3" evidence "inadequate" to make a classification. Column 4 displays the pre-agreed-upon phrases for describing zones of certainty. Column 5 shows the ratio of the reviewers imputed posterior odds to the reviewers imputed prior odds (more about this below). In column 6, the reviewers graphed their best-judgment degree of certainty as an "x" and indicated their uncertainty with a shaded bar on either side of that best judgment.

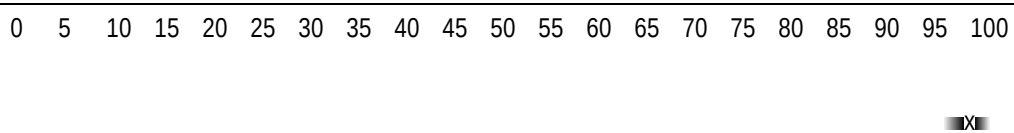
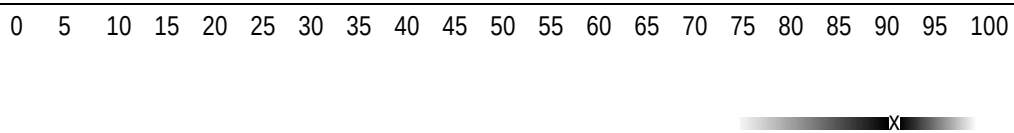
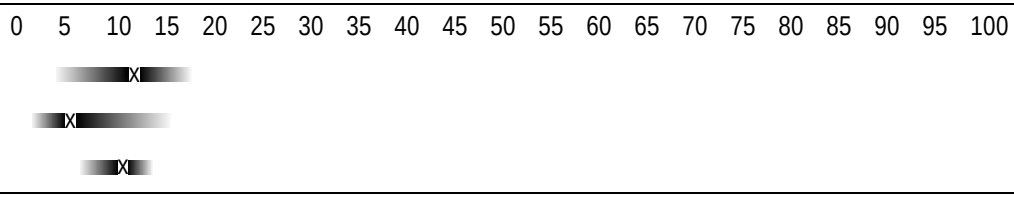
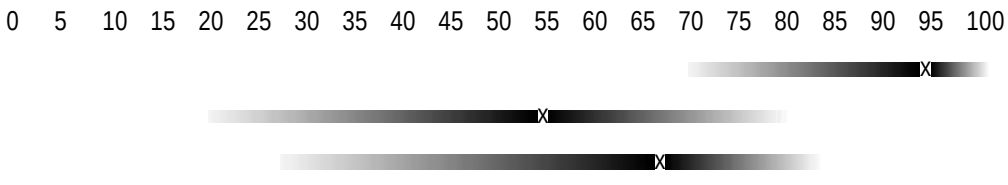
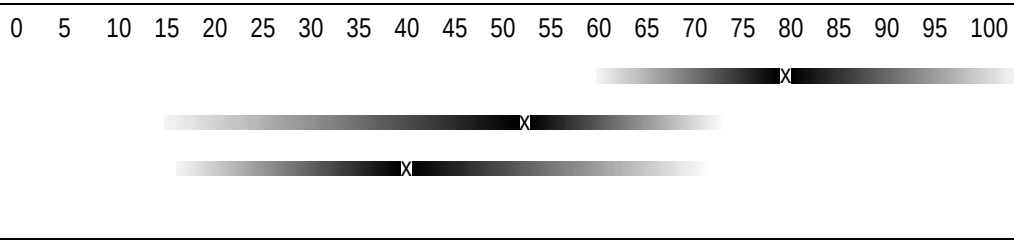
To provide an illustration, a method has been applied to two non-EMF examples in the first two rows. In row 1, Reviewer 2 has indicated that air pollution is a definite causal trigger of asthma attacks and that he is virtually certain of this. In row 2 he shows that he strongly believes that particulate air pollution causes excess deaths. There is relatively little uncertainty around either of these determinations.

Row 3 displays the prior degree of certainty that there would be epidemiologically detectable effects when comparing disease rates among persons exposed to EMFs at or above the 95th percentile of US residential levels to rates at or below the 1st percentile residential exposure. These prior degrees of certainty range from 5 to 12 on a scale from 0 to 100.

Column 5 is labeled "IRL" for "imputed relative likelihood." If the degree of certainty is converted to a probability scale (0–1.0) and, in turn, if one converted the probability to odds (probability/1–probability) the imputed prior odds can be compared to analogously calculated imputed posterior odds. One would base these on the "best judgment" posterior degrees of certainty graphed in Table 21.1. The resulting "imputed relative likelihoods" provide some indication of how much the overall pattern of evidence in biophysics, mechanistic, animal pathology, and epidemiological streams of evidence have combined to move the reviewers from their respective starting degrees of certainty. For example, with regard to air pollution triggering asthma attacks, the existing evidence has caused Reviewer 2 to move 900-fold from his prior, while the childhood leukemia evidence has moved him 22-fold*. Royall (Royall, 1997) has suggested anchoring the interpretation of such relative likelihood numbers on the relative likelihoods derived by probability theory from the following hypothetical experiment: Suppose that a reviewer has two urns, one that contains only white balls, the other that contains half white balls and half black balls. He takes one of the two urns at random. To determine which urn he has ended up with, he begins repeatedly withdrawing a ball and then replacing it in the urn (after noting down its color) and mixing up the balls before pulling out yet another ball. If on only one draw he were to find a black ball, he would know that he was dealing with the urn containing 50% black balls. But what is the relatively likelihood conveyed by drawing one or more consecutive white balls? Royall demonstrates that drawing 5 white balls in a row conveys a relative likelihood of 32, while drawing 10 consecutive balls conveys a relative likelihood of 1,024. Reviewer 2 views the asthma/air pollution data as being almost as strong as the evidence conveyed by drawing 10 consecutive white balls during the urn experiment, while the childhood leukemia evidence is equivalent to drawing just shy of 5 consecutive white balls.

* Reviewer 2 had a prior of 0.05 and a posterior for childhood leukemia of 54. The prior odds are 0.05/0.95 = 0.0526. The posterior odds are 0.54/0.46 = 1.174. The imputed relative likelihood is 1.174/0.0526 = 22.3.

TABLE 21.1 SUMMARY OF CONCLUSIONS ON ALL THE END POINTS CONSIDERED

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
Air Pollution Triggered Asthma Attacks (Example: Not EMF-Related)	2	Human Risk	Virtually certain	931	
Particulate Air Pollution Triggered Deaths (Example: Not EMF-Related)	2	Prob. Risk	Strongly believe	171	
Prior Confidence that EMFs Could Cause Epidemiologically-Detectable Disease	1		Prone not to believe	1	
	2		Strongly believe not	1	
	3		Strongly believe not	1	
Childhood Leukemia	1	1	Strongly believe	140	
	2	2B	Close to dividing line	22	
	3	2A	Prone to believe	17	
Adult Leukemia	1	1	Prone to believe	29	
	2	2B	Close to dividing line	21	
	3	2B	Close to dividing line	6	

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
Adult Brain Cancer					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	2B	Prone to believe	29	
	2	2B	Close to dividing line	20	
	3	2B	Close to dividing line	13	
Childhood Brain Cancer					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line		
	2	3	Prone not to believe		
	3	3	Prone not to believe		
Breast Cancer, Female					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	7	
	2	3	Prone not to believe	3	
	3	3	Prone not to believe	2	
Breast Cancer, Male					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	6	
	2	3	Prone not to believe	12	
	3	3	Prone not to believe	2	
EMF Universal Carcinogen?					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Strongly believe not	0.4	
	2	3	Strongly believe not	0.5	
	3	3	Strongly believe not	0.2	

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
Miscarriage					0 5 10 1 5 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	2B	Close to dividing line	9	
	2	2B	Close to dividing line	20	
	3	2B	Close to dividing line	11	
Other Reproductive					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Strongly believe not	0.4	
	2	3	Strongly believe not	0.8	
	3	3	Strongly believe not	0.2	
ALS (Lou Gehrig's Disease)					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	2B	Close to dividing line	9	
	2	2B	Close to dividing line	21	
	3	2B	Close to dividing line	11	
Alzheimer's					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	5	
	2	3	Prone not to believe	4	
	3	3	Prone not to believe	2	
Suicide					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	6	
	2	3	Close to dividing line	15	
	3	3	Close to dividing line	7	

CONDITION	REVIE-WER	IARC CLASS	CERTAINTY PHRASE	IRL	DEGREE OF CERTAINTY FOR POLICY ANALYSIS THAT AN AGENT (EMFs) INCREASES DISEASE RISK TO SOME DEGREE
Heart Disease					0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
	1	3	Close to dividing line	6	
	2	3	Prone not to believe	8	
	3	3	Prone not to believe	3	

21.2 How Different Is This Evaluation From The NIEHS, NRPB and IARC Findings?

As outlined in Table 21.2 below, there are both common points and significant differences between the EMF Program's evaluation and those carried out at about the same time by the NIEHS Working Group for the Federal EMF-RAPID Program (Portier & Wolfe, 1998), (IARC, 2001), and the NRPB (NRPB, 2001a), (NRPB, 2001b) (Note: The NRPB did not use the IARC classification system but expressed their conclusion using common language expressions).

The following table compares these evaluations:

Table 21.2 A Comparison of DHS Reviewers' Degree of Certainty with That of Other Agencies

HEALTH OUTCOME	NIEHS WORKING GROUP	IARC	NRPB	DHS
Childhood leukemia	2B*	2B	Possible	2B to 1
Adult leukemia	2B (lymphocytic)	Inadequate	Inadequate	2B to 1
Adult brain cancer	Inadequate	Inadequate	Inadequate	2B
Miscarriage	Inadequate	Not Considered	Not considered	2B
ALS	Inadequate	Not Considered	Possible but perhaps due to shocks	2B
Childhood brain cancer, breast cancers, other reproductive, Alzheimer's, suicide, sudden cardiac death, sensitivity	Inadequate	Inadequate or Not Considered	No for Parkinson's disease, inadequate for Alzheimer's, other endpoints not yet considered	Inadequate

* Although the majority of scientists assembled to prepare the NIEHS Working Group Report voted for a "possible 2B" classification for these cancers, the lay person's summary submitted by the Director of NIEHS to Congress stated: "ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard." (Final Report NIH Publication 99-4493, May 1999)

It is clear from Table 21.2 that, when applying the IARC guidelines, the DHS reviewers agreed with IARC and NIEHS reviewers that in many cases (e.g., childhood brain cancer and male and female breast cancer), the evidence would be classified by IARC as inadequate to reach a conclusion. One of the DHS reviewers agreed with the IARC and NIEHS on childhood leukemia. Two of the reviewers agree with NIEHS, but not with IARC, on adult leukemia. All three reviewers agreed with NRPB that EMF was a "possible" cause of ALS. Otherwise, the DHS reviewers regard the EMFs association more likely to be causal than NRPB, IARC, or NIEHS did.

It should be noted that all of the review panels thought that the childhood leukemia epidemiology warranted the classification of EMF as a "possible" carcinogen and thus did not agree with the biophysical arguments that EMF physiological effects (and therefore pathological effects) were "impossible."

There is a wide range of opinions in the scientific community as to the probability that EMFs cause health problems. The DHS reviewers provided numerical values for their degrees of confidence that risk of various diseases could be increased to some degree by EMF exposure. Other researchers have rarely packaged their judgments in this way, so it is hard to make comparisons. Judging by one such exercise that the DHS reviewers conducted (Neutra, 2001), reasonable scientists can have different ways of interpreting the data resulting in different degrees of certainty.

The three DHS reviewers have been active in the EMF field for more than a decade and are familiar with the opinions and arguments used by the scientists in scientific meetings. Since Reviewer 1 was part of the IARC-EMF review panel and all three reviewers had some participation in the earlier parts of the NIEHS process, they also have some understanding of the process by which selected panels of these individuals arrived at a group determination about EMFs. The reviewers think there are at least two relevant differences between their process and the usual procedures followed by the other groups.

First, the DHS Guidelines require that they consider the inherent tendency of the several streams of evidence to either miss a true effect, or falsely "indict" a putative causal agent. The weight given to those streams of evidence was influenced by this consideration. The standard guidelines involve discussions of whether the adjectives "limited" or "sufficient" best fit the pattern observed in a stream of evidence, and depending on the decision one makes, simple guidelines of how combinations of "limited" and "sufficient" streams of evidence influence whether a "possible," "probable," or "definite" causal status is assigned. While the DHS Guidelines allow null results of animal pathology studies using one ingredient of a mixture to get little weight, the IARC rules involve a simple combination of binary judgments about the animal and epidemiological evidence. The way the DHS reviewers used the Guidelines meant that they did not let the primarily null results from the mechanistic and animal pathology streams of evidence decrease their certainty as much as seems to be the case for reviewers in other panels. The reasons for this have been explained above. Having been less deterred by the null mechanistic and animal pathology, they were also less prone to invoke unspecified confounders and bias as an explanation for the persistent, if not homogeneous, epidemiological findings for certain health endpoints.

The other reason for the discrepancies in the DHS reviewers' IARC classification choices can be traced to differences in the procedures for combining the scientists' judgments. They found several striking differences between the IARC and this evaluation processes:

- The Panel's Composition. The EMF Program's review was carried out by the EMF Program's scientific staff and not by a large panel of experts outside the agency. An outside panel, however, evaluated the document. One could criticize the DHS panel as being too small and not diverse enough, but this is standard procedure for California government agencies. The IARC followed its usual practice of convening outside experts to write drafts, discuss the drafts, and turn these over to staff to finalize. Given the spread of the scientific opinions on the EMF issue, it is safe to say that the outcome of any review is a strong function of the working group members' belief before the review takes place. (The DHS reviewers have striven to make this transparent through the elicitation of the prior beliefs and the "pro and con" discussion.) Two unbiased ways to assemble a working group would be by random selection out of a pool of "qualified" individuals or through a conscious effort to include balanced numbers of individuals known to have opposite points of view. In the first case, the definition of "qualified" could influence the verdict of any sample, and sampling variability could yield a mix of opinions that would vary from sample to sample so that different working groups could reach different conclusions. The second procedure could be an excellent solution, if the evaluation were carried out through extensive debates and discussions, with a shared desire to come to a consensus opinion irrespective of its potential social and economic consequences. This was the original approach used by IARC (Tomatis, private communication). However, the pressure to conclude the evaluation within a short period of time led to

abandoning the discussion format in favor of the voting system. This leads to the next important difference.

- The Time Element: The meeting to draft the IARC-EMF monograph (June 2001) lasted five-and-a-half days. The vast majority of the plenary session time was dedicated to reviewing the draft chapters prepared ahead of time by designated committee members with maybe 10% of the time allowed for discussion of the rationale for reaching conclusions. Whenever a paragraph precipitated a controversial discussion, a common way out was to propose the deletion of the offending paragraph, a proposal that the time-pressured working group members were usually glad to adopt. In contrast to this process, the DHS reviewers spent innumerable hours and days, over a period of years and in consultation with independent consultants, to explain their inferences and resolve or clarify their differences.
- The Format of the Conclusion: IARC aims for a consensus conclusion. Members with more extreme views are strongly encouraged to converge on a middle of the road conclusion. In the California evaluation, if consensus could not be reached (as was the case for some endpoints), each member was allowed to express his or her personal belief. Although two of the DHS reviewers were subordinate to the third, substantial differences remained for some endpoints and are openly revealed in this evaluation.
- IARC's Voting System: The members of the working group were asked to vote separately on animal and human evidence. Although a sizable minority of the working group believed that there was limited animal evidence indicating a possible cancer risk, their opinion was not carried past that point of the process. Since the majority regarded the animal evidence as "inadequate," when the final vote on the overall evaluation was taken, the options posed to the working group's members were the majority positions, that is, that animal evidence was inadequate and epidemiological evidence for childhood leukemia was limited. According to the guidelines, these two majority positions resulted automatically in a Group 2B classification and Class 2A or Class 1 were not even considered as options to vote on, even if individual reviewers, such as Reviewer 1, might have so voted. The published monograph does not document that the minority view had in fact a higher degree of certainty of the EMF risk than the majority view.

Somewhat similar considerations apply to the NIEHS evaluation. Although the whole process lasted eighteen months, the decision was reached over the course of a week-long meeting, followed by a vote. This meeting was preceded by a series of workshops including discussions and presentations, but not all members of the working group participated in the workshops, and most of the workshop participants were not members of the working group. Therefore, the final conclusion was still the result of a few days intensive meeting, during which much of the time was devoted to revising and finalizing the wording of the final report rather than to writing about points of controversy. The working group report did document the vote count.

Apart from procedural differences, there are also philosophical differences between the various review panels. For example, with regard to adult leukemia, the IARC's evaluation differs from the NIEHS and the California evaluation because of the way epidemiological evidence was considered. Almost all the evidence on adult leukemia comes from occupational studies. The Epidemiology subgroup at the IARC meeting regarded most of these studies as being of poor quality, with within- and between-study inconsistencies. Most of the evaluation centered on the most recent large studies (Sahl et al., 1993), (Savitz & Loomis, 1995), and (Theriault et al., 1994), which contradicted each other. The DHS reviewers' evaluation considered the whole body of studies, residential and occupational. While they acknowledge that many of the studies have limitations, neither they, nor the IARC reviewers, have identified fatal flaws. For example, there is no evidence to suggest that the use of crude exposure assessment surrogates, while virtually certain to influence the quantitative estimate of risk and to frustrate any attempt to explore the dose-response relationship, introduced an upward bias in the reported association. On the contrary, the limitations of the studies may well be responsible for the inconsistencies between them. And while these inconsistencies do exist, they are not as common as the IARC evaluation may suggest. The Kheifets (Kheifets,1997) meta-analysis concludes that the body of epidemiological evidence shows a slight but statistically significant increase in risk. From a binary outcome standpoint, the studies with an RR estimate >1 are more than twice as numerous as those with an RR # 1.

Nonetheless, where the DHS and other reviewer panels agreed to assign a "possible" carcinogen label to an EMF/disease association, it is not easy to infer if there would be agreement on a degree of certainty. According to Dr. Rice, Chief of IARC's Carcinogen Identification and Evaluation Unit (personal communication to DelPizzo), "If IARC were to say that an exposure is in Group 2A, probably carcinogenic to humans, that would mean that the evidence is just a little short of certainty that the exposure in question has actually caused human cancer . . . Group 2B is the lowest level of identifiable carcinogenic hazard in the IARC system."

Finally, it must be remembered that in DHS's EMF Program, policy recommendations were addressed separately from the risk evaluation. In some other cases evaluations are part and parcel of a policy recommendation (they may include regulatory recommendations in the conclusion). This may make them more conservative, as it seems to be the case with IARC:" ... the IARC Monographs system of carcinogenic hazard evaluations is deliberately a very conservative one. There are many carcinogenic hazards in the human environment that are very real indeed, and control of exposures to those hazards is extremely important for public health. To accomplish this, it is necessary that carcinogenic hazards be correctly identified. We must avoid misdirecting public attention to any exposure of any kind that may be perceived as a hazard, but in fact is a misplaced concern." (Dr. Jerry Rice in a letter to Vincent DelPizzo, Aug 10, 2001.) The cover letter to the NIEHS report to congress concluded with a recommendation for only "passive regulatory action" (NIEHS, 1999). The DHS three reviewers have packaged their differing degrees of confidence about causality in a way that can be used in the decision analytic models prepared for the program. It has pointed out that the policy implications of this range of confidences depends on the policy framework of the decision maker: non-interventionist, utilitarian, virtual-certainty-required, or social justice. The public regulatory process will determine which one or which mixture of these frameworks will apply to govern policy. Thus the DHS risk evaluation is packaged to facilitate decision making but separates risk assessment from risk management. The fact that a reviewer may feel very certain that EMF is a risk factor for a particular disease does not imply that he or she advocates exposure mitigation.

In summary, the differences between the DHS reviewers' judgments and those of other reviewers are partly due to differences in procedure and terminology and partly due to the way those three reviewers weighed the several streams of evidence.

21.3 Differences Between DHS Reviewers

As noted above, the three DHS reviewers were not able to reach a consensus on all health endpoints. In this section, they explain the reasons behind their respective judgments.

21.3.1 Reviewer 1 (DelPizzo)

In almost all cases, Reviewer 1's posterior degree of certainty is higher than that of the other two reviewers. There are several reasons for this difference.

c) Different priors—the reviewer is generally more suspicious of man-made environmental pollutants, which have no place in the evolution process.

d) Reliance on the sign test—this reviewer has put much weight in the sign test, a simple, dichotomous test, which measures the probability of several studies erroneously reporting the existence of a risk while no risk truly exists. In many cases the test finds that this probability is extremely small, that is, the results are **unlikely** to be erroneous. In the reviewer's opinion, this test is particularly suitable to answer the simple question, is there a risk or not? rather than asking what the relative risk is. The results of this test are not changed if the outcome of one or more studies are **partly** due to bias. Some worst-case scenarios, assuming extraordinary coincidences of chance and bias acting simultaneously in the same direction, do weaken the evidence, but when a condition has been studied by many different investigators, these scenarios do not reduce Reviewer 1's belief by much.

c) Weight given to empirical results—Reviewer 1's prior was limited by the intuitive belief that the energy associated with environmental EMFs is so small that, even if these fields are potentially disruptive, the amount of disruption is insufficient to cause a biological effect. Once Reviewer 1 examined the results of *in vivo* and *in vitro* research on EMF exposure, however, he became convinced that biological EFFECTS (as distinct from PATHOLOGY) can result from exposure to levels below those which conventional knowledge considers necessary. That is, if one equates "energy" to "dose," exposure to environmental fields may be regarded as a non-negligible dose. Thus, the argument that kept Reviewer 1's prior low disappears and the possibility of a hazard, when repeatedly reported by independent epidemiological studies, becomes more credible.

21.3.2 Reviewer 2 (Neutra)

The fact that EMFs are the only agent that this reviewer has encountered for which there are theoretical arguments that no physiological, much less pathological, effect could be possible, did decrease Reviewer 2's prior somewhat. But physics applied to simplified models of biology were not convincing enough to make this prior credibility vanishingly small. This reviewer noted biological effects in mechanistic experiments in the thousands of mG but accepted the arguments that these were probably not relevant to effects below 100 mG. The few experiments that claimed to show an effect below 100 mG (the chicken embryo studies and the confirmatory studies of Liburdy's melatonin studies) were considered highly worthy of further study, but not robust enough or free enough of alternative explanations at this point

to cancel out the modest initial doubts about the energetic feasibility of residential EMFs to produce biological effects. The animal pathology studies have convinced Reviewer 2 that very high intensity pure 60 Hz or 50 Hz sinusoidal magnetic fields do not have a strong enough effect to produce consistent pathological effects in small numbers of the species and strains of animals selected for study. If these species of animals were to respond as humans are described to have done in the epidemiology, this was a predictable result even if pure sinusoidal 60 Hz fields were the active ingredient of the EMF mixture. Humans exposed to hundreds of mG, when compared to persons with 24-hour average exposures around 1 mG like electric train engineers, do not show relative risks consistently above 1.00, much less very high relative risks. Why would animals be expected to do so? Moreover, pure sinusoidal fields may not be a bioactive ingredient of the mixture, and the animal species chosen may not be appropriate models for humans. Reviewer 2 believes that the animal bioassay stream of evidence in this case is thus triply vulnerable to missing a true effect, and the null results do not reduce his confidence in an EMF effect much. The fact that there are epidemiological associations with several different cancer types and with other diseases that have different known risk factors does increase confidence somewhat but, without mechanistic reasons, not a great deal. Any changes from the prior were due to epidemiological evidence. Large studies likely to be free of selection bias carried a lot of weight. Many studies of different design and in different locations showing similar results also carried substantial weight, although Reviewer 2 only interpreted the sign test to indicate whether a meta-analytic or pooled association came from just a few large studies, or from a rather consistent pattern of result from many studies. Reviewer 2 did not think that any of the specific candidate confounders or biases that had been proposed to date for explaining away the epidemiology had convincing evidence to support it. The fact that most of the associations are not much above the resolving power of epidemiological studies left open the possibility of unspecified combinations of bias, confounding, and chance having produced these associations. This kept Reviewer 2 from having an updated degree of certainty above the certainty zone of "close to the dividing line between believing and not believing" that EMFs increase the risk to some degree.

21.3.3 REVIEWER 3 (LEE)

Reviewer 3 mainly used the human epidemiological evidence to form a posterior degree of certainty. The large number of studies showing consistent results across different study designs, study populations, and exposure assessments, as well as large, well-conducted studies with adequate power to address confounding, bias, dose response, and effects among subgroups contributed strongly in updating the prior degree of certainty. The association of EMFs with several types of disease and experimental and animal evidence were minor contributions to the updating process. Specificity, visibility, analogy, and, in general, temporality did not contribute much to the posterior degree of certainty.

21.4 HOW THE DEGREES OF CONFIDENCE AND RANGE OF UNCERTAINTY COULD BE USED IN POLICY ANALYSES

Community and stakeholder policy decisions usually are made from one or more of the following ethical perspectives: "non-interference," which emphasizes individual choice and rights free from the infringement of others and of government; "social justice," which emphasizes the protection of the weak, and rights and duties; "virtual-certainty-required," where protective action is only taken when the vast majority of scientists are virtually certain that there is a problem; and the "utilitarian perspective," which emphasizes results and the most good for the most people at the least cost. Each perspective would have somewhat different requirements for the degree of certainty of causality before initiating action.

The "non-interference" perspective seeks to avoid regulatory impingement and taxes and tends to favor "right-to-know" warnings and voluntary solutions to problems, regardless of the degree of certainty. The "virtual-certainty-required" framework would tend to require a high degree of certainty with narrow uncertainty bounds on the part of most scientists and a high probability of harm from exposure before acting on an environmental hazard. Indeed, this perspective would favor risk-assessment methods having few false positives, even at the cost of false negatives.

The "social justice" perspective seeks to avoid even the possibility of risk, particularly if the risk and the benefit are imposed on different parties. This perspective would tend to advocate protective action at lower degrees of confidence, wider uncertainties, and lower absolute probabilities of harm given exposure. It would favor risk-assessment approaches with few false negatives, even in the face of false positives. It would focus on the added lifetime risk to the most highly exposed.

The "utilitarian cost/benefit" perspective would evaluate the policy implications of the best estimate of the degree of certainty but would explore the consequences of the lower and upper bounds of the confidence that a hazard exists. It would focus on the burden of societal disease that could be avoided by EMF mitigation. Depending on the relative prevalence of stakeholders who suffer, respectively, from false positives and false negatives, the utilitarian perspective would develop a preference for risk-assessment methodologies. The reviewers would propose that the policy integration

document discuss the implications for policy arising from the range of best-estimates among the three reviewers and the range of uncertainties expressed. It should also discuss where the three DHS reviewers' degrees of confidence lie in the spectrum of scientific opinion.

21.5 Evidence of Risk Relevant for Policymakers Mindful of Environmental Justice Issues

It is sometimes alleged that lower SES subjects are more likely to live in areas with stronger environmental EMFs. Salzberg et al. (Salzberg et al., 1992) first explored this hypothesis and found only weak support for it. Bracken et al. (Bracken et al., 1998) reported a strong correlation between some SES indicators (women's occupations, house values) and the very high-current configuration (VHCC) wire code configuration. Two very large data sets collected in the San Francisco Bay Area as part of the study by Lee et al (Lee et al., 2002) found no evidence of an association between family income and measured EMF exposure. However, there was a weak association between low SES and wire code (Hristova et al., 1997). In a geographic information system (GIS) study as part of the power grid policy project, English et al. (http://www.dhs.ca.gov/ehib/ emf/ pdf/ AppendixG-GIS.PDF) examined the ethnic and income characteristics of census blocks within 500 feet of transmission lines. The proportion of black and Hispanic residents in these corridors was lower than the state average proportion. Zafanella (Zaffanella & Hooper, 2000) found somewhat higher magnetic fields in schools of lower socioeconomic status. In summary, the evidence to support the contention that the EMF exposure, if real, disproportionately affects low SES subjects is not very strong, but there is some suggestive data that decision-makers may consider when evaluating policy options.

21.6 The EMF Mixture

A variety of electrical phenomena are present in the vicinity of power lines, in-home wiring, plumbing, and appliances. These include EMFs with a variety of frequencies and orientations, stray currents from contact with grounded plumbing, and air pollution particles charged by electric fields. The epidemiological studies primarily implicate the magnetic fields or something closely correlated with them. Some researchers think that associated high- or low- frequency stray contact currents or charged air pollution particles are the true explanation rather than magnetic fields. The actions one would take to eliminate the fields are not always the same as one would take to eliminate the currents or the charged particles. There are some situations where different costly measures would be required to address the above-mentioned three possible explanations. There are other situations where one or more inexpensive avoidance actions will address all three. This additional uncertainty about what aspect of the mixture might need to be mitigated will thus provide a challenge for policymakers. The California EMF program funded policy projects to explore options that could be pursued in the face of these uncertainties (see www.dhs.ca.gov/ehib/emf). These are available to guide CPUC and other state agencies in policy formation. DHS is making no recommendations at this time.

21.7 Policy Relevant Areas for further Research

One of the major impediments to evaluating the potential bioactivity of a complex mixture is identifying the bioactive components of that mixture. This usually requires finding some kind of bioassay with which to assess the mixture and then successive fractions of it. While some epidemiologists have attempted to evaluate the effects of different aspects of the EMF mixture and some exposure analysts have attempted to characterize the occurrence and intercorrelation of its aspects, important policy-relevant questions still remain.

Experimentalists have rarely used the mixture as it occurs in real life and have focused instead on one or the other aspect of the mixture, usually pure sinusoidal 60 Hz fields at intensities far above those found in residential or blue collar occupational environments. Deeply ingrained experimental research styles and an orientation to explaining mechanisms rather than describing phenomena has meant that investigator-initiated research and even programs which attempted to guide research have rarely been characterized by progressively refined descriptions of dose response relationships to produce stronger bioeffects.

This has been compounded by the expectation of a quick resolution of the question by those who fund research, as was the case with the New York State program of the mid-1980s, the current California Program, and the recent five year federal EMF–RAPID program. As was discovered after President Nixon's "War on Cancer" in the early 1970s, research progresses slowly and in successive multi-year research cycles, with the results of each cycle governing the direction of the next. It would not be surprising if it took four more five-year research cycles to clarify the EMF issue.

This means that if one were serious about clarifying this issue there would need to be a long-term commitment to steady research funding and funding for intermittent assessments of the state of the science and research directions. Most research peer review groups would favor research where a clear bioeffect was present and credible alternative mechanisms were being explored. Those situations tend to have a high yield of early definitive results, and such results lead to continued research

funding, publications, and research career advancement. The EMF area does not fit this description, and from this perspective would receive a low priority for funding from the usual peer review study sections. Indeed, prominent researchers who doubt that there are any bioeffects, much less epidemiological effects, from the residential and occupational EMF mixture, feel there is nothing to find and have recommended that no more funding for this area be provided (Park, 1992).

Clearly the three DHS reviewers disagree with the assessment of the evidence to date and see a number of research areas which are worth pursuing that could influence and focus exposure avoidance strategies, if any. The cost effectiveness of further research has been a topic of the program's policy analysis and will be discussed at greater length in our policy integration document. The cost/benefit analysis of EMF research suggests that there is so much at stake in choosing between "expensive," "inexpensive," and "no mitigation," that more research funding can be easily justified. (http://www.dhs.ca.gov/ehib/emf/pdf/Chapter09-ValueofInformation.pdf)

The highest initial priorities for the reviewers would be to carry out exposure studies in residential settings and the workplace to see if purported aspects of the EMF mixture that would require different mitigation strategies are correlated with magnetic field exposure and could therefore explain their apparent effect. Such aspects include sudden exposures to the 60 Hz fields, such as micro-shocks, stray ground currents, and charged air pollutants. Such exposure studies would make it possible to reanalyze some of the existing worker cohorts to determine if these aspects are associated with diseases.

Rather than further pursuing new studies of rare diseases with long incubation periods, further studies of the more common conditions in which EMFs might have shorter induction periods, such as spontaneous abortion, acute myocardial infarction, and suicide should be given priority. These would be more relevant to a utilitarian policymaker.

On the experimental front, the reviewers suggest giving priority to finding reliable bioeffects below 100 mG and to carefully exploring dose response relationships and then mechanisms. The balance between investigator-initiated and programmed research, as well as the guidelines that will be used for interpreting results, need to be carefully considered.