10. Policy Implications

There is of course nothing new about a possible environmental health risk for which our scientific understanding is incomplete. Legislators and regulators have been dealing with such risks for decades. But, when we look with care at the scientific understanding that is available for 60 Hz and other low frequency electromagnetic field exposure, we discover that this particular problem maybe very *different* from previous problems in environmental risk in several ways.

First, the quality of the science that is now available is remarkably high. In contrast to a number of other known or suspected environmental health risks the uncertainty in our understanding about low frequency electromagnetic fields comes not from the quality of the science but from the great complexity of that science. It is now clear that 60 Hz and other low frequency electromagnetic fields can interact with individual cells and organs to produce biological changes. The nature of these interactions is subtle and complex. The implications of these interactions for public health remain unclear, but there are legitimate reasons for concern.

Second, because of the complexity of the science, the strategies which legislators and regulators have evolved to deal with other uncertain environmental health risks may not lead to effective results for this possible risk. Most conventional approaches to environmental regulation assume that "if an agent is bad more of it is worse". This assumption allows regulatory activity to begin before full scientific understanding is available. Because of experimental evidence of thresholds, windows, and similar phenomena (see the discussion in Section 3 and the summary in the preceding section), it is unclear whether the assumption that "more is worse" can appropriately be applied to 60 Hz fields. The implication of this is that practical regulatory standards which set a simple "safe" field strength limit can not be adequately suppported by the science that is now available. Such standards could prove expensive and might not have positive benefits. In some circumstances field strength based standards could arguably even do more harm than good. This conclusion raises the difficult policy question, if standard approaches may not work, what alternatives, do we have available? We explore this question at some length in the discussion below.

Third, the public discussion of 60 Hz fields has been almost exclusively limited to the context of high voltage transmission lines. Running across the country for great distances on large steel or wooden structures, high voltage transmission lines are visibly compelling objects. As such they offer powerful symbolic value and are a natural target for attention[17]. However, if there are serious public health consequences associated with 60 Hz fields the discussion in Section 2 in this report suggest that the fields associated with distribution lines (e.g. the wood poles in the street), building wiring, and appliances (e.g. electric blankets) could be the primary source of public health impact. To the extent this proves true, it will be important for legislators, regulators, and others to take care to think of this issue as a problem of field exposure rather than as a problem of high voltage transmission lines. Otherwise, enormous attention may be devoted to one, possibly minor, source of public exposure, while ignoring many other, possibly major, sources of public exposure.

Why not just use the standard techniques of probabilistic risk assessment and risk analysis to

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[17] In the heydays of federal power projects (TVA and Bonneville) and of rural electrification, high voltage transmission lines were widely used as a political symbol to represent the advancement of democracy through economic development. For example they figured prominently in the promotional posters and other materials developed by these projects.

decide how serious the possible risks of human exposure to 60 Hz fields maybe and develop appropriate regulatory recommendations from these studies? Under support from the U. S. Department of Energy we have tried to do this [Morgan 87a, Morgan 87b, Morgan 87c, Morgan 87d] but have found it impossible to get very far. The basic problem precluding risk analysis is the inability to define dose. We do not yet know what attribute, or combination of attributes, of the field produces public health effects. (For simplicity we will not continue to say "if any" after each mention of the word *'effects" in this discussion. However, readers are reminded that while biological effects have been clearly demonstrated, the existence of adverse public health consequences from 60 Hz field exposure is still an open question. Thus, whenever the word effects appears in this discussion, the phrase "if any" is implicitly assumed.) We also do not know the relationship between these field attributes and the level of effects. We do have a significant amount of experimental evidence that suggests that the relationship between field exposure and effects may be very non-linear, and may not increase systematically with field strength. In work we did several years ago [Morgan 83] we showed that it is possible to develop a series of risk assessment models each one of which assumes a different plausible relationship between exposure and effect and each one of which assumes a range of possible alternative values to define the strength and other characteristics of those relationships (parametric analysis). This approach can produce page after page of impressive looking quantitative results -- so many alternative possible outcomes that they are of absolutely no use from a policy perspective. Similarly, attempts to establish "upper bounds" on the estimates of possible health impact have produced bounds that are too lose to be of much use in policy considerations [Morgan 87e].

10.1. Policy Alternatives

The conventional approach to regulating environmental agents such as ionizing radiation or chemical pollutants is in terms of a standard based on a safe or acceptable level or concentration. When the details of the science are not known, risk managers can still move in the right general direction by assuming "if some is bad, more is worse" and regulating to reduce the levels of exposure. As we outlined in Section 9, without thinking critically about the underlying differences in the science, this same thinking has been applied by a number of state regulatory agencies to the topic of 60 Hz fields, with the result that several states have now promulgated fields strength standards for transmission lines which are at least talked about as safety standards.

There are however a variety of powerful forces that work to promote the adoption of simple field strength safety standards. This is the approach that regulatory agencies have habitually adopted. There are a variety of legal and institutional precedents which make a field strength standard the natural way to proceed. Because field related controversies have made it increasingly difficult for utilities to construct new transmission facilities, many utilities have recently begun to favor the issuance of such standards, so that they can say "we meet the standards" and get on with the job. But, while simple field strength standards may be administratively convenient for both regulators and utilities, they unfortunately can not be justified on the basis of the available science. If they are represented as assuring safety they may produce a false sense of protection, and in some circumstances could arguably do more harm than good.

Better scientific understanding may in the future clearly demonstrate the existence of adverse public health effects from field exposure and may point the way to specific risk management regulations. But, for the moment we have to operate with what we have. Available policy options include the following:

1. Do nothing until the science becomes better.

2. Make public information available but take no additional actions.
3. Adopt a field strength safety standard approach to transmission line fields based on the fiction that the numbers are supported by a review of the science. Ignore fields from all other sources.
4. Adopt a "similarity" based approach to transmission line fields which makes the exposures that people receive to these fields "similar" to those they receive from other sources in modern life. Ignore fields from all other sources.
5. Adopt a "prudent avoidance" strategy. That is, look systematically for strategies which can keep people out of 60 Hz fields arising from all sources but only adopt those which look to be "prudent" investments given their cost and our current level of scientific understanding about possible risks.

In parallel with these options are a set of research options which we discuss in the final paragraphs of this section.

Up until a few years ago we believe that option 1, "do nothing until the science becomes better", was preferred by the majority of informed people dealing with this topic. There are still people who argue vigorously for this option, but their numbers are declining both because of increasingly suggestive scientific findings and because of growing levels of public concern. At least in the short run, Some state regulatory agencies do appear to be successfully adopting a variant of this strategy, either because they have not had a recent request for new transmission line construction that has raised the issue or because they have been able to mount a series of ongoing studies of the problem.

Available public information on this topic is not as good as it should be. Press accounts tend to be simplistic and inflammatory. There are a few good brochures available through utilities, but there is reason to suspect that the public does not place great confidence in information on this topic provided by utility sources [Lee 86, IUS86 86]. There is a clear need for good balanced semi-technical and non-technical treatments of this topic from "neutral" government and private sources. Until recently many people familiar with the issues would have argued that active programs of public information might do more harm than good by raising concerns in large numbers of people before any answers were available. While a few might still make this argument, most would now agree that the issue has moved squarely on to the public agenda and that there is now a clear need for accurate and balanced information to inform public discussions and debates. Public information programs can take two forms, active programs which push the dissemination of information, and passive programs which provide information on request. To date most programs have been of this second variety. Whether programs of information alone are now a sufficient response to the issue of 60 Hz fields is a question which generates vigorous debate among informed workers active on this issue. Our personal assessment is that today a majority would probably argue that information alone is not sufficient.

Policy option three is to:

> "Adopt a field strength safety standard approach to transmission line fields based on the fiction that the numbers are supported by a review of the science. Ignore fields from all other sources."

It appears that this option is now being pursued by a number of state regulatory agencies. As we noted above it is also supported by a number of utilities as a simple strategy to control the issues and get on with the job. There are three ways in which a field strength based approach to transmission line field regulation can be pursued. The first is to assert that the standard grows directly from and is supported by a careful assessment of the field effects literature. While administratively convenient, our reading of the scientific literature says that the literature can not currently support such a standard. The second is not to base the standard on field effects of the sort discussed in this paper but rather to base it on considerations of safety arising from factors such spark discharge caused by induction effects in conducting objects near transmission lines. If such a strategy is pursued there is likely to be a temptation to "fudge" a bit by leaving the public communication unclear so as to imply that other health effect considerations, of the kinds discussed in this paper, have been included. Finally there is the practical consideration that at least for electric fields transmission line fields much above about 10 kV/m are clearly precluded by safety considerations and fields much below about 1 kV/m are at the level widely encountered elsewhere in the environment. This leaves a range of only a factor of ten. The temptation is to arbitrarily pick some number in this range in order to have a standard that will simplify life. Our judgment is that such considerations may have underlain some of the current state field strength standards.

As we discuss below, a field strength standard may also have a role to play in a "prudence** based approach to field exposure control. The difference however is two fold. Conventional standards maintain the position that they represent a "safe" level below which there is little or no risk. And, a conventional transmission line field strength standard deals only with exposure from transmission line sources, ignoring all others, or perhaps assuming that all others constitute "acceptable" exposures.

This leads us to our fourth option:

> Adopt a "similarity" based approach to transmission line fields which makes the exposures that people receive to these fields "similar" to those they receive from other sources in modern life. Ignore fields from all other sources.

Similarity based control sets out to make people's exposures to transmission line fields as "similar" as possible to the exposures we receive from all the other fields in our day-to-day lives: exposure from the fields from the power lines out in the street, the wiring in the buildings we live and work in, and the appliance we use during the day and sleep with at night. The definition of "similar" can get technically complicated I[Florig 86, Morgan 87c], but the idea is simple enough. A similarity based approach to transmission line field control can be justified on two possible grounds:

1. "Acceptability" - In this case the argument is that the fields to which we are all exposed from other sources constitute a socially acceptable level of risk. By making transmission line field exposures similar, we make them socially acceptable.
2. "Equity" - In this case the argument is that if transmission line fields are made similar to the fields to which we are all exposed from other sources then we are not asking residents who live along transmission line right-of-ways to bear field related risks that are any different from those born by all members of modern society.

We suspect that similarity considerations have entered, at least informally, into the decision making of several state regulatory agencies. In the case of New York State, the standard was explicitly chosen to make the fields of higher voltage lines similar to those of the 345kV lines already in wide use in the state. However, recent legal actions cast doubt on the state's assumption that the 345 kV lines are "widely accepted".

Our fifth and final option is a strategy of "prudent avoidance" of field exposures. By avoidance we mean taking steps to keep people out of fields, both by re-routing facilities and by redesigning electrical systems and appliances. By prudence we mean undertaking only those avoidance activities which carry modest costs[18]. When, as individuals, we think a risk may exist but we are not sure, we exercise prudence. For example, broccoli and cauliflower may contain anti-carcinogens. Dietary fiber may help to reduce the risk of certain cancers. Conversely char-grilled meats may carry increased risks of cancer. The evidence on these things is suggestive but inconclusive. As a matter of prudence many people have tried to increase the frequency with which they eat cauliform vegetables, increase their fiber intake, and reduce the amount of char-grilled meat they eat. But reasonable people do not rent a helicopter to fly high fiber bread in to them when they spend a week at a mountain ski resort which serves only regular bread. Families who eat meat, would not buy lobster for their kids every night for a week at that same ski resort if it is the only meat on the menu that is not charbroiled. Nor do reasonable people rent their own refrigerated truck to supply them with broccoli and cauliflower when they travel in places where these foods are not available. Such steps go beyond prudence. At the least they would be foolishly expensive, at the worst, signs of serious paranoia.

What would constitute prudence in the context of keeping people out of 60 Hz fields? Here are a few possibilities:

- attempt to route new transmission lines so that they avoid people;
- widen transmission line rights-of-way;
- develop designs for distribution systems, including new grounding procedures, which minimize the associated fields;
- develop new approaches to house wiring that minimize associated fields;
- redesign appliances to minimize or eliminate fields.

If we decide to do these things we have to ask how do we avoid going overboard... how do we avoid the equivalent of renting the helicopter? The answer lies in asking how much we should be prepared to invest in avoiding exposing people to fields. It is fairly easy to set an upper bound on the amount we should be willing to spend. Clearly it makes no sense to invest more per person-exposure avoided than we invest per death avoided for various *known* risks in our society. In other writings we have used the rates at which our society invests in avoiding *known* risks of death and injury to develop an upper bound on the rates at which it would be prudent to invest in field avoidance [Morgan 87b, Morgan 87c]. We conclude that it might be possible to justify investment rates of up to some thousands of dollars of person-exposure avoided, but not possible to justify rates of investment in field avoidance activities that are significantly higher than this. Thus, for example, while it might make sense to work to avoid exposing people in siting new lines, in most cases, with our current knowledge, it would not make sense to tear out and rebuild old lines. Similarly it might make sense to redesign new appliances to reduce fields exposure if this can be done for small increments in their cost. It might even makes sense to selectively replace a few old appliances, such as electric blankets, with new “field-free” versions. But it probably would not make sense to throw out all old appliances before they wear out and replace them all immediately with new “field-free” ones.

To date there has been very little research on the design of strategies to reduce field exposures. We have done a small amount of work ourselves, principally in student projects [CarnegieMellon 84]. This work suggests that in many cases low-field or “no-field” solutions maybe possible at economically

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[18] Sections of this discussion draw directly from a paper by the authors which recently appeared in *Public Utilities Fortnightly* [Morgan 88]

reasonable levels. For example a low-field electric blanket might be designed by using concentric conductors in the heating elements, by using shielded twisted pair heating elements, or by using heated fluid.

In the case of transmission lines we have developed proposals for specific strategies based on transmission line siting fees which could be used to implement prudent avoidance. The basic idea is to charge the utility a fee of $X for each person who lives within **a** given distance[19] of the line. If properly implemented this approach should provide incentives for the utility to avoid exposing people up to a marginal investment rate of $X per person-exposure avoided. We have argued that the revenue generated by such a scheme should be used to support 60 Hz health effects research. Details on this strategy can be found elsewhere [Morgan 87d, Morgan 88]. If a fee based approach is considered unacceptable, various second-best administrative procedures may be used to achieve similar goals. For example, if it was undertaken with the explicit recognition that it did not represent a "safe" exposure level, a field strength standard might be justified in terms of *'prudent avoidance" arguments.

Society has trouble doing collectively things that we do as individuals all the time. In particular, the notion of exercising social prudence on a possible but uncertain risk such as 60 Hz fields is a non-standard strategy for social risk management. To implement it will require some behavioral, political and perhaps even some legal changes. For example, as noted above, with some careful engineering, the field exposures associated with many appliances could probably be dramatically reduced or eliminated, at only modest increases in price [CarnegieMellon 84]. Suppose, that in the spirit of prudent field avoidance, an electric blanket company decides to redesign their blankets to make them "field free". It seems only a matter of time before the company will be facing litigation from leukemia victims which argues that the electric blankets caused their cancer and that the fact that the company has recently redesigned their blankets "proves" their claim, since otherwise why would the company have gone to the trouble to introduce the new design.

To date there has been very little work done on field avoidance strategies. There is clearly a need for a series of careful engineering, economic and legal studies. While DoE supports research on 60 Hz health effects, primarily from **a** transmission line perspective, neither they nor any other agency appears to have yet assumed responsibilities that span the full problem, including distribution, building wiring and appliances. Clearly, such research is needed if we wish to be able to develop **a** set of coherent and rational responses to the problem of general social exposure to 60 Hz fields.

10.2. Strategies for Research

Recent years have seen dramatic developments in the science which have prompted many observers to conclude that the issue of possible 60 Hz health risks should be taken seriously. In parallel with these developments, the past several years have also witnessed a marked decrease in the level of federal research support in this area which has only recently begun to reverse. The reductions do not appear to have sprung from any deliberate choice to reduce 60 Hz field effects research. Rather, they appear to have been the byproduct of high level efforts to limit the level of overall federal expenditures.

[19] The avoidance distance used in such a scheme would typically be significantly greater that the widths Of current transmission line rights-of-way, which would be retained and could be widened.