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Introduction

Given the considerable public concern about possible health risks from exposure to power frequency electric and magnetic fields, what kinds of exposure controls would members of the public select on the basis of their current knowledge and beliefs? The answer might be expected to depend upon the costs of exposure controls, the extent to which people are familiar with the state of the evidence, and the extent to which they consider risks from field exposure plausible.

This paper reports the results of a study using a survey instrument to present 40 options to reduce or eliminate exposure to fields from 60-

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Hz electric power to an opportunity sample of adults from the Pittsburgh area. The respondents can be reasonably characterized as "middle income, lay opinion leaders," i.e, they have a somewhat higher level of education and are somewhat more likely to be involved in leadership positions than the general public. The exposure control options ranged from voluntary design, measurement and information guidelines to banning sources of high or unusual fields. Respondents rated the options as "should definitely be done," "uncertain," or "should definitely not be done." Additionally, all subjects rated their degree of belief in health effects. A majority of subjects favored implementing twelve of the options proposed. These twelve options are characterized by restrictions on new sources of high fields, including overhead distribution and transmission lines and wiring in new buildings, and providing field information on new appliances. Surprisingly, asking respondents to estimate the costs had no significant overall effect on preferences for exposure control options, although the cost estimates produced tended to be reasonable. Insensitivity to the fact that field strength decreases with distance was approximately equally prevalent in this study as in a previous study of lay perceptions of fields.[1] Although most subjects were moderate in their beliefs (less than 10% thought that serious health effects from exposure to electric and magnetic fields were "unbelievable" or "not only believable, but true"), stronger beliefs in health effects correlated positively with preferences for implementing more exposure reduction strategies. Overall, subjects appeared to favor field limitation measures that could entail significant investments, especially for new sources.

Study Design

Subjects were divided into two treatments, no-cost and cost. In the first, subjects completed a questionnaire that asked for their preferences regarding the implementation of field-exposure control. In the cost condition, the questionnaire included additional questions requesting estimates of the costs of twelve of the field control measures. A small

1 *See, e.g., Electromagnetic Fields,* Consumer Reports, May 1994, at 354, 355.

portion of both groups of respondents also received an informational brochure[2] on 60-Hz fields. The questionnaire was piloted on a half-dozen subjects and subsequently shortened, so that the no-cost version took approximately twenty minutes to complete.

Figure 1
Instructions for using the response scale

We would like you to consider each of the options given *one at a time.* If there is *any* part of an option that you think should *not* be done, check that the option should *not* be done. The following example should help you understand what we mean by this.

Suppose that we were asking you about options for protecting against household fires, and you believed that smoke alarms should be required in homes, but not automatic sprinkler systems. Here is how you would answer questions about these options:

All of this definitely should be done	Uncertain	All or part of this definitely should not be done	
☑	☐	☐	1. Require smoke alarms in homes.
☐	☐	☑	2. Require automatic sprinkler systems in homes.
☐	☐	☑	3. Require smoke alarms and automatic sprinkler systems in homes.

If you think everything listed in an option should be done, check the left-hand box by it **even if you think even more should be done.** (You will have an opportunity to tell us exactly what you think should be done if we haven't listed it among the options.) On the other hand, if an option includes anything you think should **not** be done, check the right-hand box by that option. Of course, if you are uncertain about whether some or all of the actions described in an option should be done, you should check the middle box to indicate that you are uncertain.

The questionnaire was divided into six sections. The first section consisted of two questions about prior knowledge of fields, and one that asked subjects to judge the plausibility of human health risks from exposure to fields. These were followed by an explanation of how to use the response scale. Figure 1 includes this explanation.

2 M. Granger Morgan, Electric and Magnetic Fields from 60 Hertz Electric Power: What do we know about possible health risks? (DEPP-CMU 1989).

The questions in sections two through five asked subjects if they thought each of 40 field control options should be implemented. Fields from transmission lines, distribution lines, building wiring and appliances were covered in these four sections, respectively. Figure 2 illustrates the questions for one option, together with the associated cost-estimation task that was included in the cost condition.

Figure 2
Sample questionnaire item including field reduction item (above) and cost-estimation task for respondents in cost condition (below)

All of this definitely should be done	Uncertain	All or part of this definitely should not be done	
❑	❑	❑	Require that all new overhead distribution lines be redesigned to produce dramatically lower magnetic fields.

What is your estimate of the annual increase in your electric bill over the next few years if this option were implemented?

❑	❑	❑	❑	❑	❑
less than $5/yr	between $5 and $10/yr	between $10 and $50/yr	between $50 and $100/yr	between $100 and $500/yr	more than $500/yr

Abbreviated descriptions of each of the options are provided in the right-hand column of Figure 3. In each section, questions were ordered roughly from options requiring the least intervention (e.g., issuing voluntary guidelines to the industry for low-field appliance design) to those requiring the most (e.g., banning all further sales of electrical appliances until manufacturers can reduce the field exposure they produce). The problem of defining "exposure"[3] was not discussed. The options can be characterized by whether the changes suggested focus on the dissemination of information and are not mandatory for the public (i.e., information strategies), are mandatory, affect previously established field-exposure conditions (i.e., strategies that involve retrofitting), or require a total shutdown (i.e., ban strategies). Demographic questions concluded the questionnaire.

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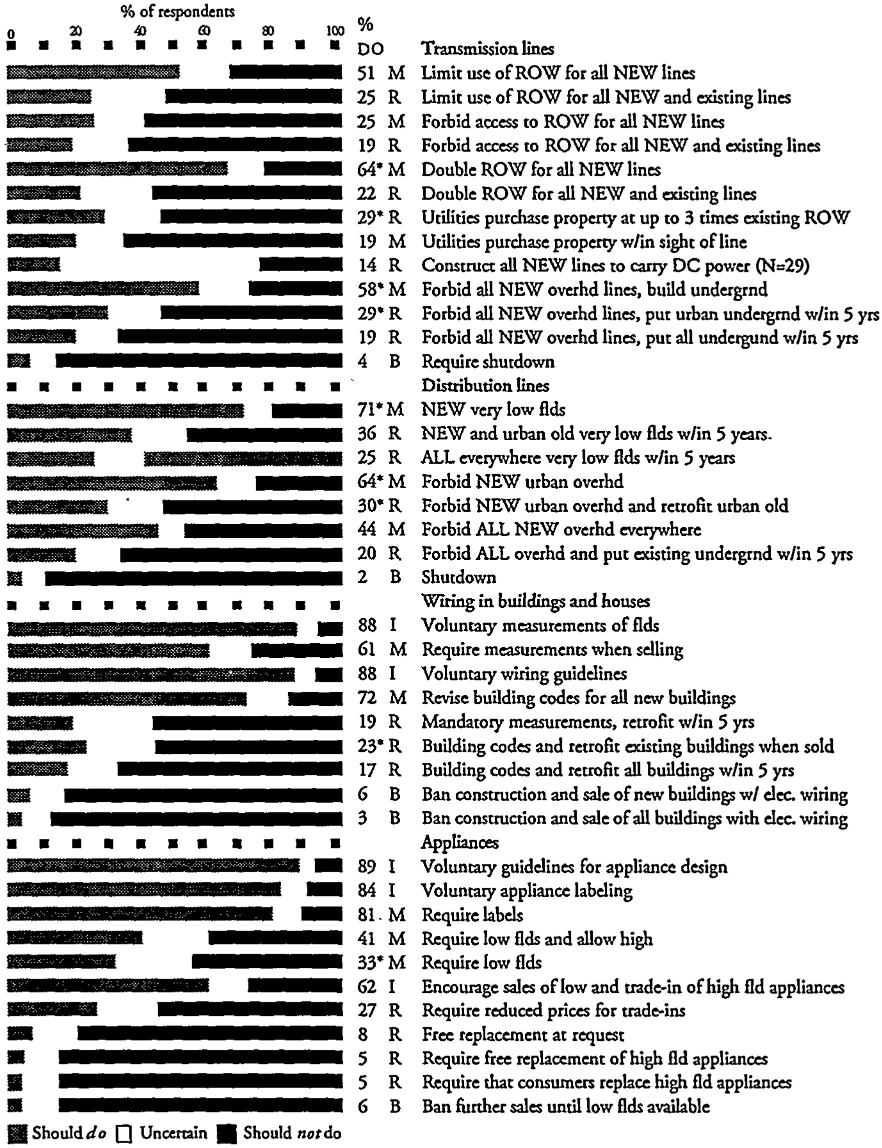
3 M. Granger Morgan & Indira Nair, *Alternative Functional Relationships Between ELF Field Exposure and Possible Health Effects: Report on an Expert Workshop*, 13 Bioelectromagnetics 335 (1992).

Figure 3[4]

Responses to field-exposure reduction and elimination options



4 (N=199). ROW = right-of-way, I = information strategy, M = mandatory, R = retrofit, B = ban. *Included cost task.

The field control options used can be classified into four general categories: those that focus on information dissemination and are not mandatory (I); those that specify some mandatory action but do not require retrofitting existing facilities (M); those that involve retrofit of existing facilities (R); and those that involve a ban on a product or activity (B). Each field-exposure control option was independently coded into one of the four strategies by two coders. The independent codings agreed on 38 of the 40 options, and the disagreements were resolved. The codings are shown in the center column of Figure 3.

Subjects

Questionnaires were distributed during the Fall of 1990 to an opportunity sample of adults whose children were members of the Fox Chapel Hockey Club, to adults who were members of the Pittsburgh Association of Society Executives, and several friends and associates identified by both groups. The sample could be described as "white and middle income." The parents of Hockey Club members have heterogeneous careers. They are on average better educated than the average U.S. citizen and more likely to be involved in executive or other leadership positions, but they come from several communities with varied incomes. Many are involved in community activities. The members of the Pittsburgh Association of Society Executives are similar, although all are employed in semi-technical administrative positions. These groups were chosen as convenience samples of typical "community opinion leaders," the sorts of reasonably well-educated, active people to whom others might turn for advice and community leadership in the event of a controversy over power line siting. We gave $8.00 to the club for each completed response received, all of which were usable. Table 1 characterizes the sample. The majority of respondents (65%) had completed an undergraduate college education and about half (53%) were female. Most were homeowners, and most did not consider themselves technically minded. The sample can reasonably be characterized as consisting of "lay opinion leaders."

Table 1
Demographics of Respondents.
Percentages have been rounded and do not include missing answers.

• *Education*	
Some high school	2%
Completed high school	12%
Completed undergraduate college	35%
Graduate school	30%
Education involved significant technical or scientific training	29%
Education did not involve significant technical or scientific training	71%
• *Technical-mindedness*	
Considers self technically or mechanically inclined	37%
Does not consider self technically or mechanically inclined	63%
• *Gender*	
Male	47%
Female	53%
• *Age*	
Under 20 years	1%
20–40 years old	42%
40–60 years old	48%
Over 60 years	9%
• *Health*	
Health Excellent	58%
Health Good	38%
Health Fair	4%
Health Poor	1%
• *Employment status*	
Employed	85%
Unemployed	6%
Student	3%
Retired	6%
Homemaker	8%
Blue collar	4%
White collar	62%
Service	26%
• *Reading habits*	
Reads newspapers daily over 30 minutes	43%
Reads newspapers daily under 30 minutes	30%
Reads newspapers occasionally	27%
Reads newspapers rarely	1%
• *Residence*	
Homeowner	80%
Renter	13%
Live with family or friends, without rent	7%

The use of such opportunity samples is rather common practice in studies of risk perception,[5] particularly when the objective is to study inferences about risk rather than to sample well formulated beliefs. In previous research on public understanding of the physics of fields,[6] very similar results were found in opportunity samples and a true random sample, although a small effect from the higher educational level of the opportunity sample was observed.

Results

Of 425 questionnaires distributed, 199 (47%) were returned, all usable. The response rate varied by condition, with lower returns on more time consuming tasks. On the basis of discussion with the leader of the two groups, we have no reason to believe that the attributes of the non-respondents were significantly different than those of the respondents, with the one exception that respondents were probably more interested in the topic. Of those involving the no information condition, 94 (62% of the 152 distributed) were returned in the no-cost condition and 81 (52% of 156) were returned in the cost condition. Response rates were much lower in the information condition. Six (17% of the 35 distributed) were returned in the no-cost condition and eighteen (22% of 82) were returned in the cost condition. Although those who received the brochure appear slightly less likely to say that any given option should be implemented, differences are not statistically significant ($t = -1.38$, $p = 0.17$). Given the low response rate for the information treatment group, no further separate analysis of these data was undertaken. Responses were judged to be sufficiently similar to justify combining the information and no information conditions in the subsequent analyses of preferences for exposure control options.

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5 Sarah Lichtenstein et al., *Judged Frequency of Lethal Events,* 4 J. Exp. Psych.: Hum. Learning & Memory, 551 (1978). Donald G. MacGregor, *Worry about Technical Activities and Life Concerns,* 11 Risk Anal. 315 (1991).

6 M. Granger Morgan et al., *Lay Understanding of Low-Frequency Electric and Magnetic Fields,* 11 Bioelectromagnetics 313 (1990).

Most respondents (83%) had heard of electric and magnetic fields. This information came primarily from respondents' general education or the news media (i.e., television, newspapers, magazines). A majority (66%) had also heard of the possibility of health effects from exposure to fields. Of those who had heard of fields, 84% found human health risks believable, compared to only 75% of those who had not heard of fields. Of those who had heard of the possibility of health effects from exposure to fields, 89% found human health risks from exposure to fields believable, compared to only 70% of who hadn't. It is interesting to compare these results with responses to a 1990 survey commissioned by Edison Electric Institute.[7] In a nationally representative sample, 38% had recently heard something about environmental effects of electric and magnetic fields, and 35% reported hearing about health or environmental hazards associated with transmission and distribution lines. It seems likely that the difference between our sample and the EEI sample reflects three factors: the greater amount of information we were able to provide to our sample respondents, the higher education level of our sample, and the fact that because they were self-selected, our respondents probably had more interest in the topic.

Analyses of the effects of the experimental conditions and of differences in preferences related to education and gender are followed by exploration of the relationship between beliefs in health effects and preferences for field-exposure reduction or elimination.

Cost Estimates

Respondents in the cost condition were asked to estimate costs for nine different options,[8] involving a total of twelve different estimates. For each such estimate, subjects were asked to respond as if "the option were implemented everywhere in the U.S. and the costs were somehow spread equally across all electric power consumers in the U.S." Costs were framed in terms that would be most relevant to the respondents.

7 Edison Electric Institute, Quarterly Public Opinion Review: American Attitudes toward Major Issues Facing the Electrical Utility Industry, EMF — Pts I & II, 1st Quarter (1991).

8 *See* starred options in Figure 3; *see also* Appendix I (Responses to All Cost Questions) and II (Summary of Cost Calculations).

For example, respondents were asked to estimate costs of power line controls in terms of the amount of average annual increase in the respondents' electric bill over the next few years for implementing the option. To illustrate, the first option cost-condition respondents were asked to estimate by cost was doubling the right-of-way for all new transmission lines. The expert estimate for an upper bound on the cost of this option was $9 a year. Subjects were given a choice between six ranges: "less than $5 per year," "between $5 and $10 per year," "between $10 and $50 per year," "between $50 and $100 per year," "between $100 and $500 per year," and "more than $500 per year." The mean, median and modal responses for this option coincided at "between $10 and $50 per year," which is the next response category higher than the highest spanned by the expert estimate.

Relative to an expert estimate of these costs, the median and modal lay estimates fell in the correct interval for eight and seven of the options, respectively. Median lay estimates were one or two response categories higher than the range spanned by the expert estimate for three of the thirteen options. Although this illustrates a slight tendency to overestimate the costs, given the numerous uncertainties in estimating such costs, subjects responded with relatively realistic estimates. Details of the lay cost estimates are provided in Appendix I.

Effects of the Cost-Estimation Task on Preferences

Explicit consideration of costs was hypothesized to dampen preferences for implementing field reduction or elimination options by bringing budget constraints to mind. A simple comparison of the proportions of subjects who preferred to implement each option by cost condition shows the proportions to be similar on all options. Where they differ, differences are small, and the proportions are sometimes greater for the cost condition (e.g., 28% of the cost and 22% of the no-cost respondents favored forbidding access to rights-of-way for only new transmission lines) and sometimes greater for the no-cost condition (e.g., 24% of the cost and 26% of no-cost favored forbidding access to rights-of-way for all new and existing transmission lines).

A simple regression of the proportions of those preferring to implement each option in the cost condition on the proportions of those in the no-cost condition shows that the proportions are highly correlated ($R^2 = 0.96$), the constant is indistinguishable from zero ($t = 1.06$, $df = 39$) and the regression coefficient is highly significant and indistinguishable from one ($\hat{\beta} = 1.0$, $t = 31.10$, $p < 0.001$). The regression was actually performed on the arc sine square root transformations of the proportions, to meet the standard regression assumptions. By chance, a much larger proportion of women respondents were in the no-cost than in the cost condition, but there is no difference by cost condition controlling for gender. Given that the cost-estimation task had no detectable effect on expressed preferences, the cost and no-cost conditions are combined in the following analyses.

Comments on the questionnaire indicated that subjects in the no-cost condition were cognizant of the importance of considering costs. Of the 21 subjects in the no-cost condition who wrote comments on the questionnaire, one-third mentioned cost. This may partially explain the similarity between the two groups. Other possibilities are that subjects' priors are higher than actual costs, which the cost-estimation task helped them approach, or that the cost-estimation task design did not effectively increase subjects' attention to costs.

Overall Preferences

Most options were unsupported by the majority of respondents, but some strategies were consistently supported across the four exposure domains. Figure 3 summarizes the pooled results for all options.

Expanding or managing the use of rights-of-way would be an inexpensive way to reduce exposure. However, of these options, only limiting use of rights-of-way (51%) and doubling rights-of-way (64%) under new transmission lines were favored by a majority of the respondents. Yet, a majority would bury new transmission lines (58%) and new urban distribution lines (64%). Consistent with observations in previous studies,[9] new lines are consistently treated differently. This is

9 Gordon Hester et al., *Small Group Studies of Regulatory Decision-Making for Power-Frequency Electric and Magnetic Fields,* 10 Risk Anal. 213 (1990).

illustrated by the smaller proportion of respondents who favor doubling rights-of-way under existing lines (22%), burying existing urban overhead transmission (29%), and burying distribution lines (30%) (see Figure 3). Many respondents did, however, comment on the desirability of longer time spans for retrofitting. The questionnaire suggested that five years be allowed for addressing existing conditions, whereas some respondents wrote comments suggesting that ten to twenty years would be more appropriate. For example, one respondent wrote: "Five years is too short a compliance term. I would have voted for some of the changes if existing facilities had 15 years to comply."

By examining the percentages of subjects preferring to implement double width rights-of-way (ROW), optional property purchase at up to three times ROW, and optional property purchase within sight of the line, one can see that approximately 20% of respondents were insensitive to the way in which field strength changes with distance from the line. This is roughly consistent with the findings from previous investigations of lay perceptions of fields,[10] showing lay people tend to substantially underestimate the rate at which field strength declines with distance. It is an open question whether education about how field strength declines with distance would change these preferences.

Respondents generally favored new low-field designs, where they were suggested. Seventy-one percent favored new low-field designs for distribution lines. A majority (61%) would also like to see sales of low-field and trade-ins of high-field appliances encouraged.

The informational strategies represented in the first few wiring and appliance options are also very popular. Most respondents want to see voluntary measurements of fields from wiring in building and houses (88%), voluntary wiring (88%) and appliance design (89%) guidelines, and voluntary appliance labeling (84%). Slightly fewer would like to see required building codes for wiring in all new buildings (72%), required measurements of fields from wiring at point of sale (61%), and required appliance labeling (81%). Several respondents mentioned that they would like to see more insulation and shielding strategies. For

10 Morgan et al., *supra* note 6.

example, one wrote "What about shielded cables? What engineering studies have been done on how to reduce levels?"

Given the choice between increasing research efforts to find out "exactly what health risks there may be from electric and magnetic fields" or immediately taking "strong action to reduce exposure to electric and magnetic fields even if it means higher electric rates," only 18% of a nationally representative sample choose immediate strong action,[11] up from 11% in 1987. This could relate to how people interpreted "strong action." Very few respondents chose the ban options in any domain, showing they were careful to reject extreme strategies (see Figures 3 and 5). Nevertheless, a majority of respondents in our survey endorse a number of field control actions now, including giving the public more information about fields, low-field designs, and burying transmission and distribution lines. Consistent with this, the 1991 EEI survey also showed that 61% of people polled favor regulation of fields from transmission lines, up from 51% in 1987.

Individual Differences in Overall Field-Control Preferences

Previous research has sometimes shown that women are more concerned about environmental risks than men,[12] for which reason we expected women to favor field-exposure reduction or elimination on average more than men. Technical-mindedness, which was self-reported, was expected to correspond to a pro-technology attitude, and hence a weaker preference for field-exposure controls. Table 2 shows the proportion in favor of each kind of field-exposure control strategy, averaged across the options categorized as that kind of strategy. While there is little difference between technically and non-technically-minded women, men are on average less inclined to favor all strategies than women, and non-technically minded men somewhat more likely

11 Edison Electric Institute, *supra* note 7.

12 Thomas A. Arcury, Susan J. Scollay & Timothy P. Johnson, *Sex Differences in Environmental Concern and Knowledge: The Case of Acid Rain,* 9/10 Sex Roles 463 (1987); T. Jean Blocker & Douglas L. Eckberg, *Environmental Issues as Women's Issues: General Concerns and Local Hazards,* 70 Soc. Sci. Q. 586 (1989); Gregory W. Fischer et al., *What Risks Are People Concerned About?* 11 Risk Anal. 303 (1991).

to favor most strategies than technically-minded men. These general tendencies appear even when controlling for beliefs in health effects.

Table 2
Percent age of respondents favoring field-exposure reduction strategies by gender and self-judged technical-mindedness.

Strategy	Men "*Technical*" (N = 54)	Men "*Not Technical*" (N = 35)	Women "*Technical*" (N = 15)	Women "*Not Technical*" (N = 90)
Information	72%	83%	88%	87%
Mandatory	41%	51%	64%	57%
Retrofit	16%	19%	30%	25%
Ban	3%	2%	12%	4%

Belief in Human Health Risks from Exposure to Fields

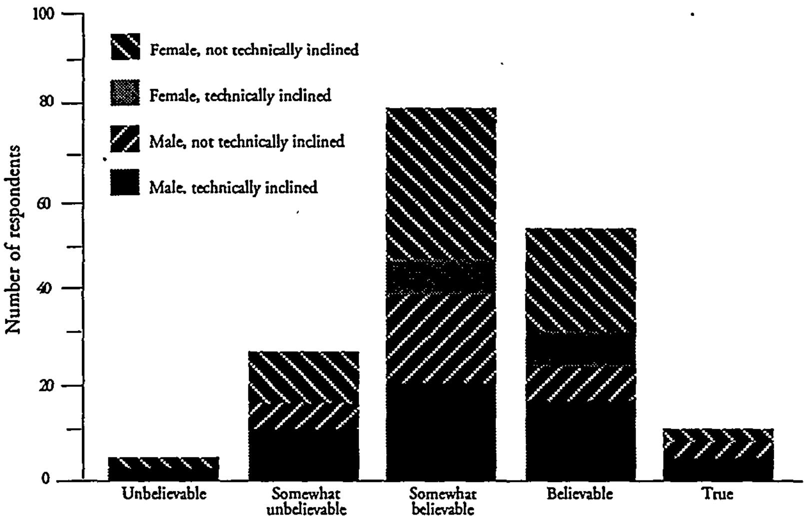
The question on degree of belief in health effects was worded thus:

> How plausible do you think it is that exposure to the electric and magnetic fields from electric power poses a serious human health risk that is, does this idea seem believable to you, does it seem to make sense?

Subjects were given a responsė choice of "unbelievable, the idea that electric and magnetic fields might cause serious human health risks just doesn't make any sense at all to me," "somewhat unbelievable, the idea that electric and magnetic fields might cause serious human health risks does not make much sense to me," "somewhat believable, the idea that electric and magnetic fields might cause serious human health risks does make some sense to me," "believable, the idea that electric and magnetic fields might cause serious health risks makes a lot of sense to me," and "not only believable, but true, I am fairly certain that electric and magnetic fields actually do cause serious human health risks." Again, strong beliefs in risks could be expected to correlate with stronger preferences for exposure control.

Figure 4 shows the distribution of beliefs in health effects by gender and by technical-mindedness. More people find health effects believable than not. As Figure 4 also shows, women tend to find effects from exposure more believable than men. Several respondents spontaneously mentioned the lack of knowledge about possible risks from fields. Their comments indicate that at least some are sensitive to the degree of scientific uncertainty about health risks from fields. One respondent wrote "Need more studies on health effects from exposure." Another said, "It is not clear what type of damage occurs from these lines (if any)." A third wrote "A risk factor has not been determined. Let's not go crazy trying to control an unknown risk."

Figure 4
Degree of belief in human health risk from exposure to 60-Hz electric and magnetic fields



How, and to what extent, does a respondent's prior beliefs about possible risks from exposure effect the exposure options they prefer? The answer, is that stronger beliefs in health effects are consistently associated with a stronger preference for implementing a given field-exposure control option. However, across the four general strategies, retrofits are less popular than prospective mandatory controls. Finally, no group shows significant support for strategies that involve bans.

Reaching these conclusions required a statistical analysis that uses Bayesian updating procedures, but the details can be skipped by nontechnical readers. The analytical results, in the form of posterior distributions of preferences for exposure control (0 = don't control, 1 = do control) are shown in Figure 5 by degree of belief in effects from fields, and by strategy. These probability density functions are calculated assuming a uniform [i.e., "uninformative," beta (1,1)] prior distribution. An updating procedure incorporates the data, as illustrated in the equations below.[13] x_i is an individual's choice to implement a specific option (1 = do; 0, otherwise).

$$x_i \sim \text{Bernoulli}(p)$$

Prior:

$$p \sim \beta eta(\alpha,\beta),\ \alpha = 1,\ \beta = 1$$

Posterior:

$$p \mid x \sim \beta eta(\alpha',\beta'),\ \alpha' = \sum_{i=1}^{n} x_i,\ \beta' = 1 + n - \sum_{i=1}^{n} x_i$$

Table 3
Example of posterior distribution for the strategy: Forbid all NEW overhead lines, build underground

	Total Respondents	Respondents who chose to do this	Posterior Distribution	Posterior Expectation
Unbelievable, Somewhat unbelievable	33	9	β (10,25)	0.285
Somewhat believable	85	43	β (44,43)	0.505
Believable, True	76	60	β (61,16)	0.792

13 Morris H. DeGroot, Optimal Statistical Decisions (1970).

Figure 5

Posterior distributions for respondents' preferences for control options, by health effects belief and strategy type. Curves indicates results for a prior belief that health effects from fields are unbelievable or somewhat unbelievable, somewhat believable, or believable or true.

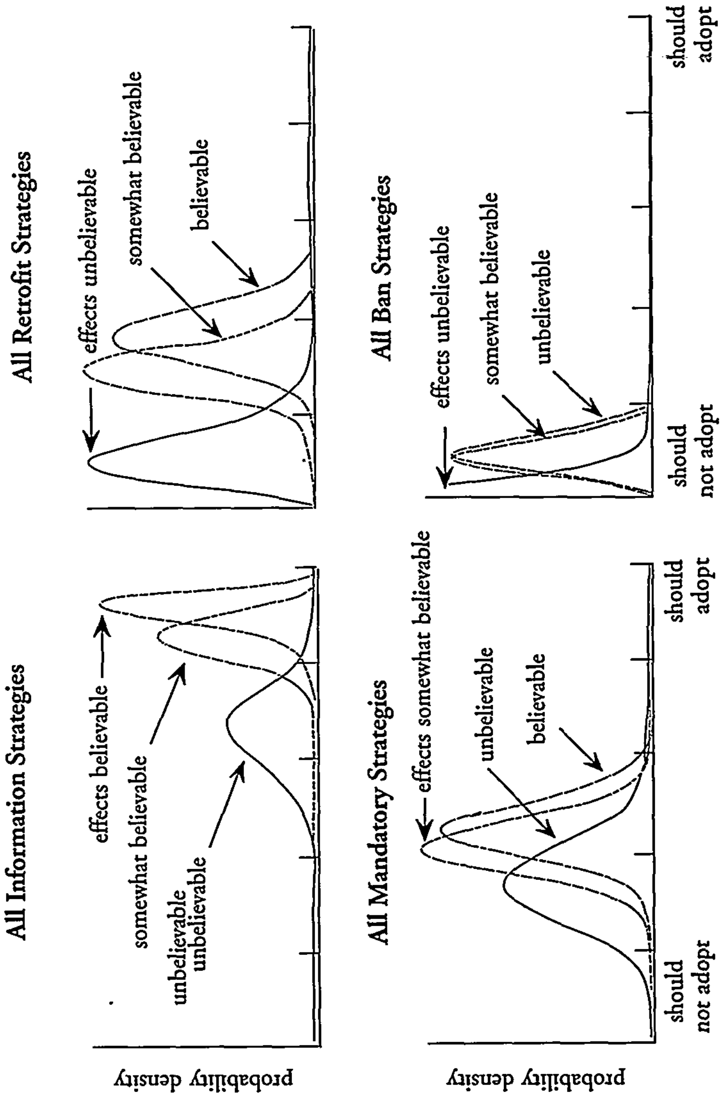


Figure 5 illustrates the posterior distributions across all options for each strategy, by belief in human health risks from fields. The calculation of these distributions by strategy treats an individual's responses to each option of that strategy type as independent. Although this assumption may seem strong, options differ in many regards (e.g., source of fields, type of action proposed, proposed actor, cost). These specifics, like the specifics of a referendum, may cause individuals to assess various options from the same strategy differently, despite the individual's general level of preference for that type of strategy. For comparison, the distributions for a single option from each of the four strategies are also shown.

Discussion

Power frequency electric and magnetic fields have recently received much media attention. This is due undoubtedly to advances in the science of fields as well as to changes in lay perceptions of fields. Regardless of the cause, lay preferences for field-exposure reduction or elimination are also increasing in importance and can be expected to play an increasingly central role in regulatory and management choices involving exposure reduction as well as in litigation.

Preferences expressed in this study show that our sample of lay opinion leaders is willing to endorse even potentially costly options for field-exposure reduction or elimination. Information oriented exposure reduction options were generally preferred by most respondents, regardless of their degree of belief in health effects from exposure to fields. New lines and wiring were treated differently from those already existing. Hence adding retrofitting to an option, such as doubling the right-of-way for old as well as new transmission lines, reduced preferences for the option. Bans were generally eschewed by respondents. On average, women favored field controls more than men, and non-technically-minded men more than technically-minded men. Such differences may increase the likelihood that some social groups will have trouble comprehending others' attitudes toward field control.

Common misconceptions, such as underestimating how fast field strength drops off with distance, may affect the kinds of policies people request or endorse. The strong association between beliefs in human health effects and preferences for field-exposure control implies that if people have misconceptions about health effects,[14] those are also likely to affect their preferences. Future work on the relationship between preferences, knowledge, and attributes of specific field-exposure controls should further clarify what various interest groups pay attention to, and why.

Because these results are from an opportunity sample, care must be exercised in extrapolating them to other settings. As citizens become more aware of the topic, previous studies we have completed suggest that their level of concern is likely to increase.[15] In addition, people in settings that involve actual controversies over facilities citing are likely to favor greater levels of field-exposure control. Both of these considerations suggest that, if they contain a systematic bias, the results reported here may underestimate the level of field-exposure control that the public will desire in many settings

Appendix I
Responses to All Cost Questions

8. When constructing *new* transmission lines double the width of the required right-of-way in order to keep most human activity at a greater distance. What is your estimate of the average annual increase in your electric bill over the next few years if this option were implemented?

11%	24%	26%	25%	9%	0%
<$5	$5–10	$10–50	$50–100	$100–500	>$500

10. When constructing new transmission lines keep the width of the right-of-way as it is now, but, at the time the line goes in, offer the owners of all buildings located at distances of up to three times the current width of the right-of-way the opportunity to sell their property to the utility at fair market prices, independently assessed without the line. The utility could resell it (perhaps at a loss) to other people who do not mind being near the line. What is your estimate of the average annual increase in your electric bill over the next few years if this option were implemented?

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14 Morgan et al., *supra* note 6.

15 Donald G. MacGregor, Paul Slovic & M. Granger Morgan, *Perception of Risks from Electromagnetic Fields: A Psychometric Evaluation of a Risk-communication Approach,* Risk Anal. (in press).

8%	15%	23%	24%	16%	7%
<$5	$5–10	$10–50	$50–100	$100–500	>$500

12. Forbid the construction of all new overhead transmission lines. Require that all new transmission lines be built underground using a design that produces only very low fields. What is your estimate of the average annual increase in your electric bill over the next few years if this option were implemented?

7%	8%	25%	24%	25%	6%
<$5	$5–10	$10–50	$50–100	$100–500	>$500

13. Forbid the construction of all new overhead transmission lines. Require that all new transmission lines be built underground using a design that produces only very low fields. In addition, require that all existing overhead lines in urban areas be replaced with low-field underground lines within the next five years. What is your estimate of the average annual increase in your electric bill over the next few years if this option were implemented?

4%	7%	13%	16%	24%	21%
<$5	$5–10	$10–50	$50–100	$100–500	>$500

16. Require that all new overhead distribution lines be redesigned to produce dramatically lower magnetic fields. What is your estimate of the average annual increase in your electric bill over the next few years if this option were implemented?

15%	17%	30%	17%	10%	2%
<$5	$5–10	$10–50	$50–100	$100–500	>$500

19. Forbid the construction of all new overhead distribution lines in urban and high density suburban areas. Require that all new lines in these areas be built underground using a design that produces very low fields. What is your estimate of the average annual increase in your electric bill over the next few years if this option were implemented?

10%	12%	24%	22%	19%	5%
<$5	$5–10	$10–50	$50–100	$100–500	>$500

20. Forbid the construction of all new overhead distribution lines in urban and high density suburban areas. Require that all new lines in these areas be built underground using a design that produces very low fields. In addition, require that, in these areas only, all existing overhead distribution lines be replaced with low-field underground lines within the next five years. What is your estimate of the average annual increase in your electric bill over the next few years if this option were implemented?

5%	8%	22%	16%	22%	10%
<$5	$5–10	$10–50	$50–100	$100–500	>$500

29. Revise building codes to require low-field wiring in all new buildings. In addition require that all existing buildings be rewired to conform to the new code whenever they are sold.

The costs of changing houses to reduce field exposures would not necessarily be spread equally across all electric power consumers in the U.S. Individual consumers would probably pay most of these costs. The following questions ask you to estimate how much some costs for individual consumers would increase if this option were implemented. We understand that you may be unsure of the costs. Please just give your best guess.

(a) Please estimate the increase in the average selling price of a new house in the U.S. that would result from this requirement.

14%	14%	44%	16%	4%	4%
<$0.5K	$0.5–1K	$1–2.5K	$2.5–5K	$5–10K	>$10K

(b) Please estimate the increase in the average selling price of an existing house in the U.S. that would result from this requirement.

9%	13%	29%	25%	17%	3%
<$0.5K	$0.5–1K	$1–2.5K	$2.5–5K	$5–10K	>$10K

37. Require appliance manufacturers to design, manufacture, and offer for sale new "low-field" appliances and to discontinue selling all "high-field" appliances. The costs of changing appliances to reduce field exposures would not necessarily be spread equally across all electric power consumers in the U.S. Individual consumers would probably pay most of these costs. The following questions ask you to estimate how much some costs for individual consumers would increase if this option were implemented. We understand that you may be unsure of the costs. Please just give your best guess.

(a) Please estimate the increase in the average price of an electric blanket for a queen-sized bed that would result from this requirement.

6%	22%	45%	13%	9%	1%	0%
≤$2	$2–5	$5–10	$10–25	$25–50	$50–100	>$100

(b) Please estimate the increase in the average price of a small table fan that would result from this requirement.

18%	37%	29%	9%	2%	1%	0%
≤$2	$2–5	$5–10	$10–25	$25–50	$50–100	>$100

(c) Please estimate the increase in the average price of an electric range (one that includes both stove top burners and a single oven) that would result from this requirement.

3%	4%	12%	24%	26%	21%	6%
≤$2	$2–5	$5–10	$10–25	$25–50	$50–100	>$100

Appendix II
Summary of Cost Calculations

Amounts in 1990 dollars

8. Estimate average annual "increase in your electric bill" if new lines were to have double right-of-way (ROW). New transmission construction cost has ranged from 2.6–4.6 x 10^9 $/y over the decade from 1979–89, which amounted to 1.4–2.8% of total revenue.[16] Assume future construction costs fall in this range. Estimates of land

16 *Annual Statistical Report,* 203 Elec. World 61–68 (1989).

acquisition costs from two utilities: 10–22% of project (Seattle City Light), and 11–18% of project (TVA). Assume 10–44% to include possible rising costs. Average residential electric bill in 1990 was 737.57 $/y.[17] Then estimate costs as (fraction of revenue due to transmission) x (fraction of transmission costs due to land) x (average residential bill) = 1.03–9.06 $/y.

10. Estimate average increase in residential bill if utilities are required to offer to buy homes within three times ROW width for new lines. Over next ten years, average of about 2,700 circuit mi/y of lines are planned.[18] Assume yearly range falls between 2,000 and 4,000 mi/y. Use average ROW of 45–65 m, and housing density in range of 25–150/mi^2.[19] The number of eligible buildings/y is calculated as (new mi line built) x (mi^2 of eligible land per mi of line) x (buildings mi^{-2}) = 7–121 x 10^3. Non-residential structures are not included in this estimate, so the upper bound may be low.

The median sales price of existing one-family homes in 1989 was $93,100. However, about 1/3 of housing is multi-unit. Assume average costs of buildings next to new lines falls in the $100–200K range. Although we are aware of no studies demonstrating significant depreciation of buildings next to lines, we will assume that a utility would lose 1–10% of the purchase price of buildings it buys near a line when reselling buildings to those who do not mind being near a line. In the years 1980–90, residential customers accounted for 40 plus or minus 2% of total revenue, and in 1990 there were 95.8 x 106 such customers.[20] Estimate cost increase as: (Eligible buildings) x (cost/building) x (% lost when buying and then reselling building) x (% of total revenue paid by residents) / (number of residents) = 0.03–10.10 $/y.

12. Estimate annual increase in residential bill if all new lines must be undergrounded. Since costs and power capacity vary widely at different voltages, transmission will be divided into three classes for this and the subsequent question. Lines with voltages of 71kV and above will be considered in this and the subsequent question. Of total lines in service in 1987, 28,000 miles were 401kV and above (8.9%), 108,000 miles were 189–400kV (34.2%), and 181,000 miles were 71–188kV (57.3%).[21] Assume that 20–30% of 189kV and up is in urban, and 80–90% of 71–188kV is in urban.[22] To calculate miles of line/y in each class, in urban: (total circuit miles added) x (fraction in voltage class) x (fraction in urban). Cost of new lines, based on survey of several utilities: 138kV overhead (OH) urban: 627k$/mi, rural 200k$/mi.138kV underground (UG) urban 2,442k$/mi, rural about

17 *Annual Statistical Report*, 205 Elec. World 9–14 (1991).

18 *Annual Statistical Report*, *supra* note 16.

19 H. Keith Florig & M. Granger Morgan, *Measurements of Housing Density Along Transmission Lines*, 9 Bioelectromagnetics 87\ (1988).

20 *Annual Statistical Report*, *supra* note 17.

21 John Stovall, National Forecast of Transmission Line Mileage, Talk given at EPRI meeting, Monterey, CA, Jan. 1991.

22 Private communication with Richard Kennon, EPRI (1991).

1000k$/mi. 230kV OH urban 730k$/mi, rural approx 420k$/mi. UG urban: 2,622k$/mi, rural: 1000k$/mi. 500kV urban OH: 1,100k$/mi, rural 800k$/mi.

To use UG instead of OH, need more UG since it has lower power carrying capabilities. Assume ratio of UG to OH for same total power capacity to be 1.07:1 at 138kV and 2.01:1 at 230kV. At 500kV there is no UG — assume it would take 7.48 230kV UG lines to carry the same power. To calculate increase in $/mi to install UG instead of OH: ($/mi for UG) x (OH:UG power carrying ratio)–($/mi for OH). Total cost is sum of (miles built) x (increase in $/mi) x (% of total revenue paid by residents) / (number of residents) for both urban and other, for all three classes = 20.23–55.63$/y.

13. What is cost if no new OH can be built, and existing UG in urban must be replaced? Amortize the costs over 20 y. Assuming interest could range from 8–12%, and that amount N is borrowed in equal amounts of N/5 over the next five years, yearly payback is from 0.081 to 0.097 N. Estimated miles of OH line to be replaced = (circuit mi) x (% in urban) for each class. The cost to replace existing OH with UG is: ($/mi for UG) x (power carrying ratio). Total cost = sum of (total miles to be replaced) x (cost/mi) x (% of total revenue paid by residents) / (number of residents) x (amortization factor) for the three classes + (result of q.12) = 234.72–414.62 $/y.

16. How much would typical residential bill increase if new OH were of "low-field" design? In the years 1979–1989, amount spent on OH distribution was 2.8–5.4 x 109 $/y. To install OH designed to significantly lower fields, cost increase would be about 10–20%.[23] Estimate bill increase as: (cost of OH) x (% increase in costs) x (% of total revenue paid by residents) / (number of residents) = 0.28–3.55 $/yr.

19. How much would annual bill increase if all new distribution in densely populated areas had to be undergrounded? Assume between 25% and 75% of all OH distribution is in urban and dense suburban. Cost of undergrounding: based on a survey of three utilities, will use a range of from 3:1 to 8:1 as the cost ratio of UG vs. OH. To install UG instead of OH, it would cost an additional 2 to 7 times the original OH cost. Calculated increase in bill = (cost of OH) x (% in urban) x (UG:OH cost ratio–1) x (% of total revenue paid by residents) / (number of residents) = 5.55–124.29 $/y.

20. How much would bill increase if all new distribution in densely populated areas were placed UG, and additionally all existing OH in those areas were placed UG over the next few years? Will take range of total value of OH to be 41.9–46.3 x 109$ — including poles, towers, fixtures, conductors, and line transformers.[24] Assume average depreciation of 1/3 to 2/3. We will assume that a range of 50–75% of all OH is

[23] Luciano E. Zaffanella, Magnetic Field Management, Overhead Power Lines, 1991 EPRI EMF Science and Communication Seminar, 1991.

[24] Financial Statistics of Selected Investor-Owned Electric Utilities, Table 26, 40–41 (1989).

presently in densely populated areas. The reason for using a higher lower bound for existing OH in urban than for OH now being built (q. 19) is that there is a strong trend in densely populated areas towards installing UG. Estimate increase in bill as: (present value of OH) x (reinflation factor to account for depreciation) x (% in urban) x (UG:OH cost ratio) x (amortization factor) x (% of total revenue paid by residents) / (number of residents)+(result from q. 19) = 29.65–478.70$/y.

29a,b. If "low-field" wiring were required at the time of sale, how much would the cost of a) new and b) used homes increase? Cost ranges for wiring new and re-wiring existing structures were obtained from three contractors — one (Clark Electric) in rural Massachusetts, two (Best Electric and Capozzi Electric) in Pittsburgh, PA. To install wiring in a new home, the estimates obtained ranged from $2,800–12,000. Materials account for about 50% of the cost, and assume materials for "low-field" wiring are 10–50% above conventional. For new homes, the total increase would be 5–25%, or $140–4,000.

Estimates we obtained of the cost to completely rewire existing buildings before they are sold ranged from $4,200–15,000. Using 10–50% materials cost increase, the range for "low-field" rewiring is $4,305–18,750 when complete re-wiring is required. Many homes, especially newer homes, might be "retrofit" at low cost, since applying a few key mitigation techniques may be adequate. Average cost increase is thus estimated to be $1,000–8,000.

37a. How much more would a "low-field" electric blanket cost vs. a standard blanket? Low-field blankets have already been introduced on the market, and if retooling, engineering R&D, etc., are amortized over the next five years, then the cost increase is in the $2–5 range.[25]

37b. How much more would a "low-field" table fan cost than a standard one? Could put more metal in housing or other parts of the magnetic circuit, or could put a thin sheet of copper, aluminum, or special composite material around the motor, in order to generate counter fields. Neither of these strategies should increase costs by more than 50–100%. The price of small table fans is $5–10. Cost increase is estimated to be $2.50–10.00.

37c. How much more would a "low-field" electric stove cost than a standard one? The cost of a no frills electric stove is about $329. Most of the fields from the stove will be from the elements. Assume elements account for from $100 to $150. The increase in the elements portion could be as low as 10%, and up to 100% if factors such as R&D are included. This results in a cost increase in the $10–150 range.

25 Private communication with Sunbeam Northern (1991).