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# Appraising the precautionary principle – a decision analysis perspective

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**Abstract**

**The public and regulators are naturally concerned about any decision that has uncertain but potentially serious health and environmental consequences. When facing such decisions, some individuals say we should resolve significant uncertainties before taking expensive action that may be unnecessary. Others support the precautionary principle, which says that policy makers should err on the side of caution by acting now to avoid or limit potentially detrimental consequences. This paper appraises the precautionary principle from a perspective decision analytic point of view. We argue that neither the 'resolve uncertainties before taking action' nor the 'act now on the side of caution' are appropriate as general policies for all environmental decision problems. Instead, we conclude that policy makers need to conduct sound, in-depth analyses to resolve the pros and cons of acting now versus conducting more research on a case-by-case basis.**

KEY WORDS: risk, decision analysis, precautionary principle

## 1. Introduction

Many societal decisions have to be made in the face of substantial uncertainty about their health and environment consequences. Examples are decisions on how to manage nuclear waste, how to deal with global warming, and whether to reduce exposures to electromagnetic fields (EMF) from powerlines.

The purpose of this paper is to appraise the precautionary principle as a guide to health and environmental decision-making. A prescriptive, decision-analytic view is taken in this appraisal. As decision analysts, we do not believe that either the 'resolve uncertainties, before taking action' nor the 'act now on the side of caution' policies are appropriate for all decision problems. Instead, we begin with the precept of applying common sense and sound analysis to each problem. For some decision problems, this will suggest more research, for others, moderate action, yet for others, immediate and strong action. Throughout the paper, decisions about reducing electromagnetic fields from electric powerlines will be used to illustrate our viewpoint.

## 2. What is the precautionary principle?

The precautionary principle is a guideline stating that actions should be taken now to avoid possible future health and environmental consequences that could be potentially

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very serious. However, the principle does not clarify what actions should be taken or how one should reasonably select those actions. Indeed, there are many different statements that describe the precautionary principle with different implications for what might be appropriate actions. For example:

1. The precautionary principle states that 'rather than await certainty, regulators should act in anticipation of environmental harm to ensure that this harm does not occur' (Bodansky, 1991).
2. 'The precautionary principle ensures that a substance or activity imposing a threat to the environment is prevented from adversely affecting the environment, even if there is no conclusive scientific proof linking that particular substance or activity to environmental damage' (Cameron and Abouchar, 1991).
3. The precautionary principle applied to protect the environment implies that 'where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation' (United Nations, 1992).
4. The precautionary principle says that to avoid irreparable harm to the environment and to human health, precautionary action should be taken: whenever it is acknowledged that a practice (or substance) could cause harm, even without conclusive scientific proof that it has caused harm or does cause harm, the practice (or emissions of the substance) should be prevented and eliminated (Rachel's Environment and Health, 1993).
5. The precautionary principle requires that 'when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context, the proponent of the activity, rather than the public, should bare the burden of proof. The process of applying the precautionary principle must be open, informed and democratic, and must include potential affected parties. It must also involve an examination of the full range of alternatives, including no action' (Wingspread, 1998).

These different statements describing the precautionary principle present a similar spirit that might be characterized as 'when uncertain, err on the side of caution, and act not to prevent future harm.' However, the statements are not completely consistent with each other. Statements 1 and 2 want to ensure that no adverse consequences occur. However, statement 2 implies that there might already have been significant scientific investigation without conclusive proof of adverse environmental harm. Statement 3 is much less forceful, as might be expected as it was drafted by a collection of nations. It basically says that waiting for full scientific certainty is not a reason for postponing action, but it also suggests that any implemented action should be cost-effective. Statement 4 is the strongest statement of the precautionary principle in that it says action should be taken to prevent and eliminate any harm that might occur. Statement 5 adds a couple of aspects to the precaution principle, namely to involve the stakeholders in the process and to consider the full range of alternatives.

Whether or not the precautionary principle is appropriate depends on the decision-making context and how it is used in this context. The context may be a very specific decision, for example, whether or not to retrofit transmission lines in residential areas to reduce the potential risks from exposure to electromagnetic fields. Alternatively, the context may be the decision of choosing a policy guideline, for example, whether to implement a conservative guideline for reducing electromagnetic fields exposure from transmission lines. The way the principle is used can also vary substantially, for example, as a general rule of common sense (when in doubt, balance caution and cost-effectiveness considerations) or a stricter implementation (e.g., when there are uncertainties, always implement policies to reduce the possible health and environmental consequences).

## 3. Realities of risk decisions

In this section three complexities inherent in all risk decisions are discussed. Because they are inevitable, they are considered to be 'realities' that affect the consequences of any alternative chosen on a specific risk decision. For each reality, how the precautionary principle deals with it is briefly reflected on.

Since we frequent refer to risk, the term should be defined as it is used. In this case, the meaning of risk is taken to be an uncertain and negative impact on human health and well-being. In most cases described below, we discuss life-threatening risks meaning those imposing a chance of death.

### 3.1. REALITY 1: UNCERTAINTIES ABOUT RISKS CAN NEVER BE COMPLETELY ELIMINATED

Regardless of what is known or done at a given time, there will always be some uncertainties about how the future will unfold. In risk decisions, we care about consequences to humans. Humans have free-will to act as they wish in the future and we cannot predict all human actions with certainty. Thus, even if all of the 'science' about a given risk is known, which is almost never the case, important risk decisions will always have uncertainties.

A natural response to the fact that risk decisions have to be made in the face of uncertainties is to insist on more studies, before taking action. In the EMF area, for example, the problem of uncertainties for risk estimation is especially complex. First, there are some who argue that EMFs cannot possibly cause cancer because of the low energy levels associated with EMF exposure. Second, even those scientists who think that there are possible biological mechanisms that could produce an EMF-health link at low energy levels, disagree about the nature of that mechanism. Third, there is disagreement on the appropriate exposure metric (e.g., time-weighted averages of magnetic fields, time above certain thresholds, or rapid changes of the field). Such uncertainties are unlikely to be completely resolved in the foreseeable future.

Some have argued that in the face of such significant uncertainties, no action should be taken to mitigate EMF exposure until these uncertainties have been eliminated or at least drastically reduced. Others have argued that some version of the precautionary principle may be appropriate, for example, by taking actions that reduce exposures substantially, but cost nothing or very little (Morgan 1992). Moving an alarm clock a little further from the bed and avoiding electric blankets are examples.

The precautionary principle is a direct response to the argument that decisions cannot be made until all uncertainties are eliminated or at least substantially reduced. In fact, several statements of the principle mentioned above argue that it is appropriate to make cautious decisions in the face of uncertainty, rather than waiting until research provides the final answer.

### 3.2. REALITY 2: RISK DECISIONS INVOLVE CONFLICTING OBJECTIVES AND DIFFICULT TRADEOFFS

Decisions about risks also involve considerations of nonrisk concerns. These may include objectives to reduce economic costs or to improve the quality of life. Risk reduction and other objectives of dealing with risks tend to be in conflict: Once dominated alternatives are eliminated from consideration, better achievement of one objective can only be accomplished at the expense of reducing achievement of another objective.

For example, concern with EMF may lead some people to reduce electricity consumption by curtailing their use of certain appliances. This would reduce the comfort and enjoyment that the use of those appliances supply. Undergrounding transmission lines is very expensive and will increase electricity rates. Reconfiguring powerlines by spacing lines them more closely together causes difficulties in maintenance and may require planned shut downs of lines during service, thus increasing outages. On a more general level, all risk reduction actions incur costs, both monetary and nonmonetary, and the marginal cost of reducing risks generally increases substantially as one tries to reduce risks further and further.

When making decisions about risks, the multiple objectives mentioned above will need to be appropriately balanced by trading them off against each other. This requires value judgments. For example, if individuals contemplate changing the wiring or grounding configurations in their home to reduce EMF exposure, they will have to trade off costs and hassles of these changes versus the exposure reduction. If state agency officials consider setting field strength limits for existing transmission lines, they would have to trade off the potential risk reduction against the costs and the possible indirect risks resulting from the regulation.

In almost all risk problems, alternatives can be created that have a lower risk of life loss, but cost substantially more than a riskier alternative. Whether one decides to improve the electric wiring in a home, to adopt field strength standards, retrofit existing substations, or take any other action to reduce EMF exposure, these decisions will cost money. Thus, in any of these decisions, cost and risk of life loss must be traded off when making risk decisions. Since there is no possibility to avoid that tradeoff, it is not unethical to address it according to most, if not all, moral theories. Some people confuse making value tradeoffs between costs and the risk of life loss with putting a price on human life. However, even if statistical expected lives lost are not valued explicitly, they are valued implicitly by any action (or nonaction) taken.

The precaution principle does not explicitly address conflicting objectives nor the need for making tough tradeoffs. Rather, the precautionary principle suggests that it is appropriate to take action that errs on the side of caution. In practice, this often means making decisions based mainly (or only) on the health and environmental consequences and neglecting cost and other non-risk consequences.

### 3.3. REALITY 3. ACTIONS TO ADDRESS RISKS INDUCE POTENTIALLY SIGNIFICANT INDIRECT CONSEQUENCES

If the precautionary principle is applied to reduce a particular risk, it may inadvertently introduce greater risks. For instance, if a utility were forced to reduce occupational exposures to electric and magnetic fields below certain thresholds, it may result in a required change of the practices of the workers. As an example, Dillon and von Winterfeldt (2000) analysed implications of a 10 Gauss occupational threshold limit on a utility's work practices of maintaining and repairing high-voltage transmission lines. Since the normal practice of using barehanded work on these lines might sometimes lead to exceeding the 10 Gauss limit, an alternative of using hotsticks or de-energizing the lines prior to work would be required. With both the use of hotsticks and de-energizing lines, the time required to perform the job would be increased and hence, the exposure to worker related risks, like falls and cuts, will be increased. In addition, with an alternative such as de-energizing the lines, there is a slightly greater chance that there would be an outage in the system somewhere because there are fewer options for delivering electricity. Such an outage, which might cause traffic lights not to work and emergency equipment in homes not to function, could itself lead to additional serious life threatening risks to many members of the public.

Indirect consequences other than risks are frequently caused by actions to reduce risks. In the previous example, using hot-sticks or de-energizing lines increases both the time required for maintenance and costs. Undergrounding lines results in neighbourhood disruptions, noise, and delays to traffic.

Additional costs can lead to increased risks and other undesirable consequences. Wildavsky (1980) strongly made the case that individuals spend their disposal incomes in ways that make their lives safer, as well as perhaps more enjoyable and more interesting. Since Wildavsky's original work, others have quantified the effects that occur when disposable incomes are effectively reduced by pursuing expensive alternatives felt to be, by some, in the public's interest. The money spent by firms or the government to make alternatives safer eventually is paid for by individuals, all unnamed. These unnamed individuals are company shareholders, employees, customers, and taxpayers. Eventually all costs are passed on to regular people.

Several papers (Keeney, 1990, 1997; Graham *et al.*, 1992; Lutter and Morrall, 1994; Viscusi, 1994) have quantified the relationship between expenditures and the statistical fatalities that are induced by them. While there is no precise agreement on how much expended funds induces a statistical fatality, the figures are in the range of US$5 million to US$50 million. These certainly suggest that expenditures to reduce the risks that will avoid one statistical fatality should not be more than US$50 million. Yet, there are numerous federal programmes and regulations that spend much more, some in the hundreds of millions of dollars (Tengs *et al.*, 1995). In our judgement, it does not make good sense, nor does it make good public policy, to require actions or to act in a way that avoids one statistical fatality if it induces many more statistical fatalities.

## 4. Implications for decisions addressing risks

The three realities of risk decisions lead to three important implications for any decisions made that address these risks. Figure 1 indicates the logical implications of the realities. Their implications for use of the precautionary principle are appraised in subsequent sections.

### 4.1. IMPLICATION 1. DECISIONS MUST BE MADE WITH LESS THAN COMPLETE INFORMATION

One almost never has all the information when making a decision. If one waits until all the uncertainties are resolved to make a decision, then the decision is always to wait and no action will ever be taken.

It is therefore imperative that action be taken when there are still uncertainties, sometimes even when these uncertainties are large. Uncertainty is simply a complexity of

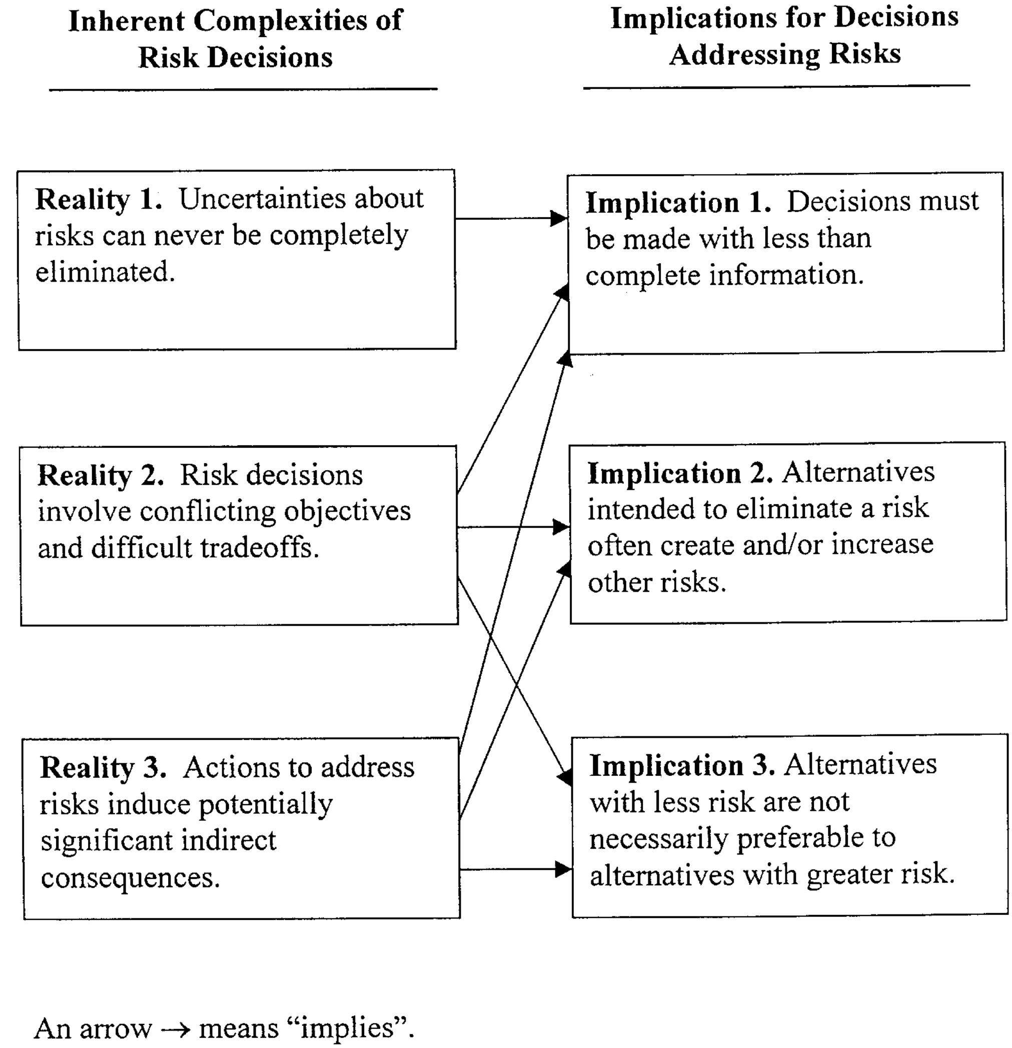


**Fig. 1.** Realities and their implications for decisions involving risks to human health and the environment.

the problem that needs to be addressed. Even if the evidence suggests that the chances of significant detrimental consequences are small, if the potential consequences are large enough, it might be appropriate to take bold action if that action were not too expensive or did not induce other undesirable consequences. The lack of a full resolution of uncertainty is no basis whatsoever for not taking action. The only basis for not taking action now is that given all things that we know (including knowing what we don't know) carefully considered, it is best not to act now.

### 4.2. IMPLICATION 2: ALTERNATIVES INTENDED TO ELIMINATE A RISK OFTEN CREATE AND/OR INCREASE OTHER RISKS

A natural response to any newly discovered risk is to try to eliminate its source. For example, when epidemiological studies first associated exposure to electromagnetic fields with cancer and other health effects (for summaries, see National Research Council, 1996; National Institute for Environmental Health Sciences, 1999), some called for action to eliminate at least some of the sources of higher exposure (e.g. electric blankets). More radical proposals include moratoria on transmission line siting and undergrounding transmission and distribution lines.

Whether or not these proposed actions are reasonable, they must contend with the fact that people's lives are embedded in various risks and that reduction of one type of risk often increases another type of risk. For example, if a new transmission line cannot be sited due to concern with EMF risks, the electrical load on the existing lines will eventually have to be increased, which increases EMF exposure to populations near these lines.

Public risk reduction policies often produce a transfer of risks from one group of individuals to another group. For example, if distribution lines are placed underground, worker accidents and fatalities are likely to occur during the construction of the lines. Road closures during construction of underground lines may limit access to emergency vehicles to the construction site and the surrounding community.

Sometimes an action that reduces risks to an individual increase some other risk to the same individual. For example, disconnecting the electric ground connection from water metal water pipes to reduce EMFs from ground currents may increase the risks of fires and electrocutions in the home.

Some indirect risks are more subtle. Collective actions taken to reduce EMFs from transmission and distribution lines are costly (see e.g. Florig, 1992). These costs would be directly passed on to the electricity consumer as well as increasing the costs of products that are created with use of electricity. As a result, individuals would have less disposable income, which could be used for other activities to reduce risks (see Keeney, 1990).

Because of indirect risks, some seemingly appealing risk reduction alternatives may cause more risk to human life that they potentially eliminate. As a specific example, the economic costs of undergrounding transmission and distribution lines might induce more deaths by making people less well off than the number of lives potentially saved due to eliminating certain EMF risks.

In principle, the precautionary principle could address these realities by considering a 'total risk account', thus shifting the argument from caution regarding a specific risk to individuals of concern to an argument for caution regarding the total risk, including indirect and unintended risks, produced by a decision. In practice the precautionary principle is more likely to be used to justify decisions that reduce the direct health and environmental risks of concern, even if the action is costly and even if it may produce other risks.

### 4.3. IMPLICATION 3: ALTERNATIVES WITH LESS RISK ARE NOT NECESSARILY PREFERABLE TO ALTERNATIVES WITH GREATER RISKS

Risk decisions must balance conflicting objectives, including costs, intended risk reductions, unintended risk increases and others. As a result, the 'best' alternative is not necessarily the one that produces the greatest intended risk reduction. Clearly, some actions may be preferred that actually have higher risks than others, as long as the other consequences of that alternative more than make up for that deficiency.

In the EMF area, studies suggest that the best alternatives are not to carry out a drastic plan to reduce human exposure to fields at all cost, but to defer extreme and costly actions until new research results justify otherwise (von Winterfeldt *et al*., 2000). However, the same studies also suggest that taking moderate action now may be better than not to take any action, even though significant uncertainties remain about the full range of consequences.

For example, when considering action to reduce fields from large transformers in office buildings, simple measures like re-arranging the office configuration or changing space use may be preferable to eliminating the EMF exposure source or substantially reducing the exposure (see Keeney and von Winterfeldt, 1996). For one, the costs of redesigning the transformer may cost millions of dollars. For another, evidence suggests that there would not be any major improvements in health or safety from this re-design. Thus, in the face of the tradeoffs and uncertainties, simple, cheap and adaptive measures may be preferable to complex, expensive and irreversible measures.

A corollary of this implication is that there is no uniformly definable 'acceptable level of risk'. Instead, what is acceptable is dependent on the problem context. The acceptable level of risk for driving an automobile need not be the same as the acceptable level of risk for flying commercial aviation, nor should the acceptable level of risk from drinking public water supplies be necessarily equal to that from smoking or skiing. The answer to the question 'How safe is safe enough?' is: It depends on the alternatives and objectives that are relevant in that specific risk problem. The acceptable level of risk should be defined as the residual risk remaining after the best alternative is chosen considering all other alternatives and all objectives of the problem (Fischhoff *et al*., 1981). The precautionary principle does not directly address this issue. Yet some of its stronger versions suggest that the focus is on 'prevention and elimination' of the risk of concern rather than on balancing intended risk reductions against unintended risks, and other costs and benefits.

## 5. Using the precautionary principle

The precautionary principle is essentially a general guideline that suggests specific types of actions in circumstances with uncertain health and environmental consequences. To appraise the appropriateness of the principle, its use is examined in specific problems first, and then its use as a general policy.

### 5.1. USING THE PRECAUTIONARY PRINCIPLE IN A SPECIFIC DECISION PROBLEM

A decision problem can be characterized by the objectives that the decision maker(s) want to achieve, the alternatives designed to achieve the objectives, and the uncertainties that prevent us from precisely knowing how well the alternatives will achieve the objectives. For example, problems involving the management of electromagnetic fields from existing electric transmission lines can be characterized by objectives like reducing health risks, reducing costs, and reducing negative impacts on property values. Alternatives include undergrounding the line at considerable expense, reconfiguring the line (e.g., by split phasing) at a much lower expense, not to change the line, or conduct more research before making a decision. Uncertainties include whether or not exposure to electromagnetic fields causes health effects, and, if so, what is the mechanism for producing health effects and how many and how serious are the health effects.

Any analysis of this problem has to deal with two issues: How to responsibly deal with the uncertainties in the problem, and how to address the tradeoffs between conflicting objectives. Decision analysis provides prescriptions: By assessing the uncertainties in the form of probability distributions and by assessing the decision maker(s) risk attitude, decision analysis formally addresses uncertainties in the problem. By assessing the decision maker(s) relative weights for the conflicting objectives, it addresses the value tradeoffs inherent in the problem. The results are a preliminary rank order of the alternatives and any sensitivity analyses that identify how strongly the preferred alternative depends on different factors (e.g., risk attitude or weights). The results are not meant to tie the decision maker(s) hands, but to provide information to make a better choice. As it turns out, in the EMF decision context, this choice is highly dependent on assumptions about the probabilities that a hazard exists, the decision maker(s) risk attitude, and the relative values of health, direct dollar cost, and property value consequences of the alternatives.

How might the precautionary be applied in this context? At one extreme, it might suggest to deal with the uncertainties by assuming the worst and to deal with tradeoffs by ignoring all but the health and environmental concerns. The implication of this application of the principle is simple: Underground the transmission line at any cost, since this is the most effective method for reducing fields. However, none of the five statements of the precautionary principle discussed earlier is that restrictive. Instead most statements emphasize the need for taking action now (rather than waiting) to reduce the potential for health and environmental consequences, even when there is no conclusive scientific proof of these consequences. Translated into the EMF example, this may suggest to either take moderate action (re-configuring the lines) or to underground the lines. It also suggests that not to do anything or to conduct more research is not appropriate. Less restrictive forms of guidance for decision making, as for example, Granger Morgan's (1992) prudent avoidance principle, would imply that only moderate actions that are cost-effective in reducing fields should be taken.

As this example shows, the decision analysis formulation may either agree or disagree with the conclusions of applying the precautionary principle to a specific decision problem. Certainly, some analyses support that it is reasonable to take some moderate action now, instead of waiting for research – at least as long as the prior probability of harmful consequences is not insignificant (see von Winterfeldt *et al.*, 2000). In general, it is agreed that it is sometime preferable to take risk reduction action now rather than to wait for more research. However, we would also argue that in some decision situations it is better to wait for more research. The choice depends on complex considerations of the value of the research, its timelessness, its cost, and the costs, risks, and benefits of the alternatives for acting now without the knowledge that the research might provide.

As decision analysts, we conclude that the application of the precautionary principle sometimes makes sense and at other times it does not. Its appropriateness often depends on the assumptions about uncertainties and tradeoffs. Without being clear about these assumptions, it is considered problematic to apply the precautionary principle without further analysis.

### 5.2. USING THE PRECAUTIONARY PRINCIPLE AS A GENERAL POLICY

Whether or not to use the precautionary principle as a general policy is a decision as well. This decision influences the many specific decisions that might be affected by the policy.

Consider the application of the precautionary principle to all EMF decisions. EMF problems include concerns with exposure from home grounding systems, transmission lines, distribution lines, transformers, and appliances. The precautionary principle applied to the class of all EMF problems would suggest precautionary action in all exposure situations, for example, by improving the net return current in homes, reconfiguring transmission and distribution lines, i.e. avoiding exposures around transformers and appliances. Some of these actions (e.g., reconfiguring power lines) involve substantial costs with uncertain or low exposure reduction benefits and others involve low costs with high exposure reduction benefits (e.g., keeping some distance from high-field appliances). Thus, one cannot avoid examining the cost-effectiveness of each EMF decision problem when appraising the appropriateness of the precautionary principle to all EMF decisions.

One cannot reasonably evaluate the appropriateness of the precautionary principle as a policy without testing its consequences for the specific decisions it guides. As stated above, it is felt that the precautionary principle may lead to good decisions in some specific decisions, and to bad ones in others. It also seems that the precautionary principle often does worse and can never do better than the following principle: In each specific decision context, select the alternative providing the best balance between the costs, risks, and benefits inherent in the problem.

## 6. Conclusions

The precautionary principle is, in part, a response to the argument that risk decisions cannot be made until all scientific evidence is in and all uncertainties are eliminated or at least drastically reduced. As decision analysts, we agree with the idea that we don't want to wait forever to obtain perfect information in order to make decisions. Responsible decision-making can and should occur in the face of uncertainty and prior to all the information being available. On the other hand, we don't want action for action's sake and we don't want action that has worse consequences than no action.

The precautionary principle has implications for many specific risk decisions. In particular, the principle suggests taking action now (rather than to wait for research) with an emphasis on reducing harmful consequences (rather than balancing the costs, risks, and benefits of all actions). In some specific decision contexts, this will lead to good alternatives, in others to poor alternatives. Ultimately, the value of the precautionary principle has to be proven by the quality of the specific decisions it produces.

It seems that the precautionary principle is not unreasonable, but that it should be refined substantially. First, the principle should be refined to require that it is not applied across the board to all decisions, but that specific decisions are examined individually. In this examination many alternatives should be considered including no action in the foreseeable future, as mentioned in statement 5 of the precautionary principle at the beginning of this paper (Wingspread, 1998). The refinement should also state that responsible action should be taken. By responsible, it is meant that a full range of objectives be specified, that the consequences with their uncertainties be investigated and described as well as possible for each of the alternatives, and that the value judgements necessary to make the tradeoffs be made explicitly and reasonably.

Also, we wish to make decisions that take into account the realities described above. We should not focus on just the risk of no action without also considering all the indirect risks and costs of the different actions and an evaluation of whether accepting those consequences is worth avoiding the former consequences of maintaining the status quo. We should explicitly make the value tradeoffs necessary to select the best alternatives in each specific decision. If laws or regulations propose alternatives that implicitly force the use of inappropriate value tradeoffs, choices cannot be made intelligently and the undesirable consequences of applying the law or regulation may outweigh their benefits.

As a general policy guideline, the precautionary principle lacks a precise definition regarding what it means, where it is used, and how it should be implemented. Within this latitude, decisions can be made in an explicit manner with a full range of alternatives and objectives and a reasoned and reasonable understanding of the consequences and value tradeoffs. If this is done, the implications can be beneficial to our society. But also within this latitude, decisions can be made that limit the set of alternatives and the consequences that might be considered. These limitations can lead to poor decision-making.

The decisions for which the precautionary principle is aimed are too important to rely only on vague guidance. For informed, responsible, participatory decision-making, more and better guidance is needed. Our recommendation is to refine the precautionary principle to promote good decision making, not to artificially constrain decision-making.

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