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Issues at the Forefront of Public Policy for Environmental Risk

Comments for the American Meteorological Society's Annual Policy Colloquium

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RESOURCES FOR THE FUTURE

Issues at the Forefront of Public Policy for Environmental Risk: Comments for the American Meteorological Society's Annual Policy Colloquium

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Abstract

The lay of the policy land for addressing and managing environmental risk includes the hillock of the precautionary principle, the mountain of the practice and ethics of monetary valuation, and the tectonic plates of real-world innovations in markets and trading exchanges for nonmarketed environmental goods. This paper offers an overview of these contemporary and as yet unresolved issues and asks how each might be addressed in disparate environmental risks such as lightning, climate change, and severe weather. The overview focuses on issues that may be of interest to the American Meteorological Society's annual policy colloquium.

Key Words: risk, environment, public policy, economics

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1. Introduction and Background

The practice of environmental risk assessment, management, and communication is at least as old as the worship of Poseidon and Venus or the construction of an ark. Modern-day risk analysts may argue that by employing today's state-of-the-art mathematical and computer tools, our approach is more sophisticated.[1] But it's also likely that 100 years from now, our current risk analyses methods will seem primitive. It's also a matter of humble debate as to whether today's tools enable results that are any better at the margin than the tools of the ancients or whether tomorrow's tools will enable results that are any better at the margin than today's tools.

Perhaps what is different today is the widespread attention throughout all echelons of modern society—the public at large; governments at the federal, state, and local levels; industry; and universities and other nongovernmental organizations—to questioning the limits and applications of risk analyses. Formal analysis of risk has broadened from application strictly to financial markets (the risk associated with business profit and loss and, later, stock market performance) to applications to address risks to health, safety, and the environment (hence, largely nonmarketed goods and services).[2] The marriage of quantitative methods with health, safety, and the environment strikes some as forced or even untenable and strikes others as a match made in heaven. A related development is that the field of risk analysis has become highly interdisciplinary, with attention not only from the natural and physical sciences but also from

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[1] Although see Plough and Krimsky (1987), reprinted in Glickman and Gough (1990). Plough and Krimsky note that structured risk analysis appears to have begun with the Babylonians in 3200 B.C.

[2] There is an often-cited distinction between risk and uncertainty: In the case of risk, probabilities are known, and in the case of uncertainty, probabilities are unknowable (the distinction is attributed to Frank Knight, 1921; see LeRoy and Singell 1987 and March and Simon 1993, p. 137). Some experts choose not to distinguish between the two (see, for instance, Freeman 1993, p. 220). Others (Clarke 1999) hinge their analyses on the distinction. The policy implications are keen, in that the effort to collect more information can reduce uncertainty and better inform risk.

philosophy, ethics, and the field of communications, including use of the Internet, high-speed computing, earth science satellites, and other information technology enabling information collection, visualization, and dissemination. As an organizing principle with which to structure the burgeoning field, around 1983 the field of risk studies formally was divided into the subtopics of risk assessment and risk management and, later, risk communication.[3] Rough definitions are that risk assessment references determination of likelihood and extent of harm; risk management addresses public policy decisions; and risk communication includes the exchange of information, concerns, and preferences between the public and decisionmakers.

The uses to which risk analyses are put range from scholarly papers to advance the science and art, to the underpinnings of public information about hazards, to required documents that accompany or undergird government health, safety, and environmental regulations, standard setting, and legal cases. In all of these applications, much remains unknown. Should a policy objective be "no risk"? Most argue that such a goal is unrealistic and undesirable, but then the question is "how much risk"? And, once having assessed risk, much is unknown about risk management and communication. These actions take place in the context of peoples' perceptions of so-called low-probability, high-consequence events, voluntary or involuntary risks, risks to older people or to children, and risks to those in developing countries compared with people in developed countries.

The objective of this paper is to highlight as a point of departure for discussion and reference the issues in environmental risk that are at the forefront in policymaking. The top three issues largely center on these concerns and developments: how safe is safe enough, as manifested in the debate over the precautionary principle and its implications; valuing property by way of nontraditional institutions (climate and weather exchanges and voluntary banking) and nonmonetized approaches such as environmental indicators; and valuing life, particularly when lives saved or changes in the quality of life are likely to accrue far into the future rather than in the next generation or two.

The next section of the paper discusses these issues and the concluding section offers a few additional observations about research directions.

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[3] Apparently a 1983 report by the National Academy of Sciences originally made the distinction between risk assessment and management, and a seminal paper by William D. Ruckelshaus in 1985 drew out risk communication (see the foreword by Paul Portney in Glickman and Gough; Ruckelshaus's paper is also included in that volume).

2. Highlights of Current Debate and Discourse

Three very different yet also somewhat similar environmental risks can serve as straw men for subsequent discussion in this section. The examples with just a few words about each follow.

Lightning: Data suggest that lightning is one of the leading weather-related causes of deaths and injuries; a source of sizeable financial risk to utilities, the aviation industry, and other businesses; and a potential natural danger to forests and other ecosystems.[4] A particularly interesting example is that of spectator safety at outdoor events during which lightning may strike.[5] The probability of the strike, the management of potentially large numbers of spectators, and mitigating actions taken in advance, such as those associated with protecting building structures and conducting public information campaigns, all figure into design of appropriate risk policy.

Climate change: The effects of anthropogenically introduced carbon dioxide and other greenhouse gases in the atmosphere, as well as the natural variability of earth's climate, potentially pose risks to human and environmental health. The nature and extent of any of these risks are uncertain and many may be manifested in damages for which the most severe effects occur only well into the future. Possible benefits associated with maintaining or improving quality of life also are likely to accrue well into the future.[6]

Severe weather: The technology and expertise specializing in identifying severe weather, together with the detailed preparation and communication of forecasts, is impressive. Gallingly, however, questions continue to loom, such as when (at what probability and how early) and how most effectively should public warnings be issued? Typically, the answer ultimately depends on a combination of factors. Essentially, what would happen in the event the public responds (say, by evacuation) and the severe weather occurs (lives and property may be saved); what would happen in the event the severe weather occurs but no warning is issued (lives and property lost); and what would happen if the warning is issued but the severe weather doesn't occur (costs of a false alarm); a fourth outcome is no warning and no severe weather.

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[4] See National Weather Association 2003, Kithil 1995, and references therein.

[5] See Gratz, Church, and Noble 2004.

[6] References to climate change sometimes focus only on human-induced change, while others include natural variability. Pielke (2004) observes that the government organizations addressing climate change are inconsistent in the relationships they assume, resulting in conflicting policy actions.

These examples have common characteristics from the perspective of risk analyses. In all three cases, mitigating actions can be taken now. But these actions are not costless. In all three cases, balancing risk in a cost–benefit framework requires valuation approaches to life, property, and ecosystems or, if a cost–benefit framework is not used, balancing risk still requires some set of measures or filters with which to make tradeoffs if the amount of resources available to address the risk is limited. In all three cases, further research in prediction and mitigation can be useful.

An additional complicating factor common to all three examples is what opportunities the public has to take action. Even if the risk of any of these three events is fully identified, well communicated, appropriately disseminated, and publicly understood, the set of actions available to or taken by those at risk may limit their response for a host of reasons. For instance, in flood-prone Bangladesh, citizens may have few alternatives among actions to respond to flood warnings. Bill Hooke has pointed out that across the United States, populations vary greatly in terms of their readiness to respond to extreme weather.[7] In Oklahoma, tornado awareness is quite high. In the Moore, Oklahoma, tornado of May 1999, only 40 people died, which Hooke notes is "a statistic considered miraculous at the time considering the strength and extent of the twister." He goes on to comment "anecdotal evidence shows that the low toll was a tribute as much to the mindset and alertness of Oklahomans as it was to the warnings themselves."[8] In short, actions taken in response to information are the denouement of risk assessment and communication but frustratingly elude much of the domain of technology and expertise.[9]

The examples also differ sharply. Of the three, lightning is arguably the closest to real-time immediacy in the issuance of a warning and public response, although as noted above, there are actions that can be taken in advance to mitigate damage. Severe weather forecasts are often (but not always) issued far in advance. Climate change poses potential risks that are generally thought to be intergenerational.

The geographic breadth, human and ecosystem effects, and time required to adjust, recover, or both also vary among the examples. These factors can significantly influence public

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[7] Hooke is the Director of and a Senior Policy Fellow in the American Meteorological Society's Public Policy Program.

[8] Hooke 2004.

[9] Macauley (2005) gives an overview of the literature on the value of information in the context of earth science and environmental data collection and decisionmaking.

perception and the political will to allocate resources toward risk management. In some sense, each of the events can be construed as low-probability but high-consequence events involving possible loss of human life, but their endpoints differ. For example, in a recent book about risk (notable if for no other reason than the book has received extensive review in the mainstream press, unlike many other books about risk), Richard Posner (2004) argues that too few resources are being allocated to averting globally catastrophic events (of the three events in the example here, only one, climate change, would be catastrophic using his definition).[10] He rests his argument on what he calls "inverse cost–benefit analysis"—the probability that is implied by dividing current government expenditures on various activities (asteroid detection, mitigating climate change) by an estimated loss of life or loss of economic activity (expressed in dollar terms) if the extreme event were to happen. The implied probabilities of a globally catastrophic event are well below the probabilities estimated by experts in these areas, leading Posner to find that too little is being spent to avoid potential losses.[11] (Interestingly, and in keeping with discussion later in this section about valuation, this inverse cost–benefit perspective is one of the more controversial parts of Posner's book.)

What measures can, and perhaps should, inform decisions about assessing, managing, and communicating risks associated with events such as lightning, climate, and severe weather? The decision "calculus" can be explicit or implied. In either case, the problem includes an expert or scientific estimate component (environmental conditions, other scientific data), a public component, including the public's perception of the risk and public willingness and ability to respond, and a trade-off, value, or other policy component that reflects choice in decisionmaking. The challenge for a decisionmaker, then, is ascertaining, at the margin, whether, when, and how best to allocate additional dollars and other resources to accommodate (or reduce) potential risk.

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[10] To pick an example, Kopp and Smith (1993) label the Exxon Valdez oil spill a catastrophic event (see p. 118). Posner differs. Invoking *Webster's Third New International Dictionary*, he notes that one definition is "a momentous tragic usually sudden event marked by effects ranging from extreme misfortune to utter overthrow or ruin." He then states that it is the top of the range ("overthrow or ruin") on which he focuses his discussion of potentially catastrophic events, including (but not limited to) pandemics, asteroids, genetically modified crops, nuclear winter, bioterrorism, and climate change (Posner 2004). See also Young (2003), who also emphasizes globally catastrophic events.

[11] In the case of climate change, Posner (pp. 181–182) uses current U.S. federal government spending on climate change research (about $1.7 billion) and assumes losses of about a fifth of U.S. gross domestic product (present value of $67 trillion) if abrupt global warming occurred. Dividing 1.7 billion by 67 trillion gives a probability of 1 in 388,000 of catastrophic global warming. Because he views this probability as too low given estimates in the scientific literature, he argues that greater investment in averting warming is justified (he argues for greater private investment, in particular).

And even if the policy objective were to save all lives and all property at any cost in any of these cases, such a goal may not be technologically feasible, even if financially feasible.

At present, the decision calculus is front and center in public argument. Much, but by no means all, study of balancing risk rests on a framework that outlines the consequences of taking or not taking the risk in quantitative terms. The use of cost-and-benefit study is highly controversial in many respects: the framework itself remains a subject of debate (how to quantify intangibles, how to adjust present and future values); the ethics of the framework are in question; and the decision point in the sense of how much risk is acceptable is always buttressed by caveats. Seminal papers representing the extremes in the arguments are Wildavsky (1979; reprinted in Glickman and Gough 1990), who argues, “No risk is the highest risk of all,” and Kelman (1981; also reprinted in Glickman and Gough 1990), who offers an ethical critique.

Table 1 and Figure 1 illustrate the typical decision framework that both parties to the debate would probably accept in general terms. Table 1 is a standard decision table illustrating outcomes under alternatives of taking or not taking action given a particular event. Figure 1 shows that the barest minimum framework as represented in the table quickly becomes complex when the “ifs,” “buts,” “ands,” and “don’t forgets” are added. The figure is adapted (and expanded here) from an extensive and detailed study of the “hidden” costs of coastal hazards undertaken by the Heinz Center in 1999 (see Heinz Center 2000). The study is a good example of an interdisciplinary, in-depth study in which the authors themselves differed in views about quantification, monetization, and “how much risk is right,” yet worked conscientiously to at least frame all of the considerations that enter into their case study.

As an example of the added complexity, from Figure 1 the standard table becomes more complicated if a long-duration time dimension is added, as in the case of climate change. With the time dimension, new concerns—such as intergenerational equity—now enter in. Those making the decision today may not be those facing consequences later. This mismatch could mean that decisions leading to benefits now and costs later are more likely if politicians tend to vote for policies that bring benefits now and for which the bill comes due later (a standard hypothesis in the field of political economy). In the case of climate change, this could imply taking no action now. Instead, or perhaps in addition, it could mean that current decisionmakers expect future generations to innovate to mitigate future costs and to do so at lower costs than if the current generation took action. The capacity of humankind to adapt to change is another hypothesis that tempers taking action now.

Another time dimension is associated with errors in the decision. A false alarm can be costly and could increase uncertainty and skepticism among the public in the future or cause policymakers to over-respond (for instance, by overbuilding evacuation routes).[12] A similar loss of confidence could occur if no action is taken but an event occurs.

2.1 The Precautionary Principle

The equity concern (as well as other concerns, particularly about the challenges of quantifying risk) has deepened the chasm between taking no risk and taking some risk and has led to increased attention to the "precautionary principle." Long studied by scholars, a version of the principle was adopted by the European Union in 1992. The principle remains contentious in the United States.

The precautionary principle is the concept that in the face of uncertainty, actions should be taken as "better safe than sorry" measures. Advocates of the principle urge its application to climate change, genetically modified food, nuclear power production, pesticides use, and other areas in which there is any chance of harm to humans or the environment. Hahn and Sunstein (2005) cite as an influential example the Wingspread Declaration issued by a group of 32 leading scholars and policymakers at a conference in 1998 (sponsored by the Johnson and Alton Jones foundations) on the use of the principle. The declaration states:

> We believe existing environmental regulations and other decisions, particularly those based on risk assessment, have failed to adequately protect human health and the environment, as well as the larger system of which humans are but a part.

And the declaration later concludes:

> Therefore it is necessary to implement the Precautionary Principle: Where an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some

[12] In the case of a real-time event, Pielke (1999) notes that Hurricane Floyd has the dubious distinction of being the first storm in which the cost of evacuation may have exceeded the cost of damages. Because of population growth along the coastline in the geographic boundary of the warning, the estimated cost of evacuation (about $2 billion) rivaled the property damage (about $1 billion in insured losses, but there were additional flood costs).

> cause and effect relationships are not fully established scientifically. (Wingspread Statement on the Precautionary Principle, at http://www.gdrc.org/u-gov/precaution-3.html)

A version of the cautionary principle was adopted formally by the European Union in 1992 after a series of public health incidents. The events included mad cow disease in humans in Great Britain, tainted blood banks in France, and dioxin-poisoned food in Belgium. According to Jonathan Wiener, who has published extensively on Europe's use of the principle, there is a widespread perception that Europe is more cautious than the United States. Wiener asserts that this perception has been shaped largely by a small number of international conflicts about genetically modified foods, hormones in beef, and climate change. However, he points out areas in which the United States has been more cautious, as in responding to threats of cancer. In other areas, such as diesel fuel, Americans and Europeans focus on different risks. Diesel fuel use is extremely low in the United States because Americans opt for stricter air quality standards, while diesel use is much higher in Europe, where regulators focus instead on keeping carbon dioxide emissions low.[13]

Critics of the principle argue that it offers no guidance on "how safe is safe enough." Posner (2004) is among the more blunt of the critics.[14] He writes:

> The "precautionary principle" ("better safe than sorry") popular in Europe and among Greens generally is not a satisfactory alternative to cost–benefit analysis, if only because of its sponginess —if it is an alternative at all. In its more tempered versions, the principle is indistinguishable from cost–benefit analysis with risk aversion assumed. (p. 140)

Critics note further that risks can arise from taking action under the principle—for example, taking action in one area, such as reducing use of pesticides, can introduce risks in other areas, such as food quality and safety. Hahn and Sunstein (2005) ask, for example, whether genetic modification of food can harm the ecology and perhaps human health or will it bring about more nutritious food and improve health? They then argue that full consideration of decisions requires balancing benefits and costs, accounting for tradeoffs between future and present risk, and weighing the value of a life today compared with one tomorrow. In their view,

[13] See Weiner 2002.

[14] See also Hahn and Sunstein 2005.

the tools of benefit and cost analysis have evolved to address concerns such as these by allowing for uncertainty, by specifying a range of outcomes, by preserving specified outcomes, or by identifying a worst-case scenario and showing a degree of risk aversion with respect to that scenario.

2.2 Valuing That Which Eludes Valuing

As Posner’s comment makes clear, valuation is entangled in discussion of the precautionary principle.

Economists have long argued that simply by making choices and taking action, values are implied in all decisions whether based on a precautionary principle or on other reasons. Sometimes these values are openly apparent—the prices of goods and services exchanged in markets (whether based on barter or money) reveal worth to consumers and producers and register scarcity (such as when prices rise or the terms of trade in barter increase). Values are apparent as well in insurance markets—for property as well as life insurance—which reveal how much risk an insured party wants to accept and how much the insurer wants as a premium in exchange for providing insurance. In other cases where the value of goods and services, such as human life or an ecosystem, are less apparent or not at all apparent, methods (albeit controversial) have arisen (and in some cases, are codified in government rules) for estimating values.

Like the precautionary principle, valuing nonmarketed goods and services and human life has long been modeled and empirically assessed by researchers. In recent years, policymakers have begun to accord valuation methods and results significantly more attention. And, independent of public policy, some very interesting developments have occurred recently in the private sector: private markets have developed as trading exchanges for hedging risks of nonmarketed goods, such as weather and even greenhouse gases.

2.2.1 Valuing Property

Insurance

One of the largest issues in property-related aspects of risk is the role of using markets to reduce risk. One example is insurance markets and the reinsurance markets that protect the primary insurance markets. These can include both government-provided insurance—the most notable example is the National Flood Insurance Plan (NFIP) and other programs—and private-market insurance.[15]

Insurance usually brings with it two well known problems. One is the problem of moral hazard, in which the insured may take less care or caution because insurance provides a safety net. The other problem is adverse selection, in which persons who want insurance are often those who are likely to need it (that is, are more at risk). Persons less at risk are less likely to want insurance. As a result, insurers are less able to pool high and low risks.

In the case of insurance for severe environmental risks to private property, analysts repeatedly find that many consumers are uninsured against damage and relatively few people take loss mitigation measures even after severe events. For example, research shows that few people undertake structural changes (such as anchoring a house to its foundation to minimize effects of an earthquake) even in the aftermath of an extreme event.[16] Assessments of the NFIP have found that it has the unintended consequence of promoting residential development in coastal areas,[17] and point out that some insured properties have four or more claims that total more than the building's value.[18] In addition, the provision of flood insurance at subsidized rates by the federal government may have crowded private insurers out of the market.[19] And, as Kunreuther et al. (1992) point out, in the event of property losses, all taxpayers, not just those in the affected area, help pay for uninsured losses through some form of disaster assistance or low-interest loans. State government and municipalities also may turn to the federal government for assistance if large numbers of public buildings are damaged.

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[15] As an example of other government programs, see Aldy (2004), who shows that the 1980 Low Income Home Energy Assistance Program, which subsidizes heating for low-income households in the winter and, in a few states, cooling in the summer, also results in reduced mortality after controlling for a host of related variables.

[16] Kunreuther et al. (1992) offer good examples.

[17] See discussion and references in Whiteman (1997). The NFIP was enacted in 1968 to limit the growth of flood control and disaster relief expenditures through a reasonably priced federal flood insurance program. The Coastal Barrier Resources Act of 1982 (P.L. 97-348) prohibited the issuance of new flood insurance coverage and other federal infrastructure assistance for some segments of coastlines to reduce the incentive to develop, but in areas not covered by the 1982 Act, federal flood insurance and other benefits remain in effect.

[18] See John (2003) and Subcommittee on Housing and Community Opportunity (1999).

[19] See John (2003). On the last two observations, John reports that about 10,000 out of 4.4 million insured properties have filed four or more claims in the last ten years or two or more that total more than the building's value. The hearings of the Subcommittee on Housing and Opportunity referenced above also focused on the problem of repetitive losses under NFIP.

Other Markets and Market-like Approaches

Another, almost brand-new, market approach to risk is the use of climate and emissions trading and exchanges, weather contracts, and voluntary "banking" programs. These provisions enable individuals to translate or characterize risks associated with climate, weather, and pollution as a standard business risk and then treat it as such.[20] That is, in practice, these provisions are a type of insurance.

Climate-related emissions trading and exchanges. In 2003, the European Union issued Directive 2003/87/EC, establishing a carbon emissions trading program. The European Union Emissions Trading Scheme (EU ETS) opened in January 2005 and has become the largest market in emissions allowances, operating on a "cap and trade" basis. Trading is web-based by way of electronic registries and accounts in EU member states. The regime enables allowances to be transferred among companies just as a banking system keeps track of funds. Firms that exceed their targeted level of emissions must buy extra carbon quotas from firms that undershoot their goals. In May 2005, Britain opened a registry for storing carbon dioxide emission allowances to enable firms to participate in the EU ETS.[21]

Since the 1980s, trading of air emissions has taken place in several U.S. states for a variety of pollutants. In 1992, the first nationwide exchange for air pollution emissions opened in the United States and provided for the trading of SO_2. Subsequently, regulators set up a market for NOx emissions in which participants exchange allowances on a daily basis. The most recent development in the United States involves carbon trading, taking place in the Chicago Climate Exchange (CCX). The CCX is a pilot program operated by the private sector. The program began in 2000 under a foundation grant administered by the Kellogg Graduate School of Management at Northwestern University. Participants, which include companies in the United States, Canada, Mexico, and Brazil, have voluntarily agreed to reduce emissions of greenhouse gases below baseline amounts by 2006, the last year of the pilot program. Members of the CCX include Rolls Royce, Ford, Dow Corning, Dupont, Motorola, IBM, and International Paper, along with electric power generators, pharmaceutical manufacturers, steel plants, and

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[20] I thank Geoff Styles, formerly in strategic management at Texaco, Inc., for pointing this out to me. See his "Energy Outlook" blog at http://energyoutlook.blogspot.com/2004/07/what-can-we-agree-on-regular-readers.html (accessed May 2005).

[21] See "CO_2 Registry Opens This Week," 2005.

municipalities. In March 2005, the CCX opened its wholly owned subsidiary, the European Climate Exchange, for trading based on the EU ETS.

The reasons for participation, according to the CCX web site, include the chance for firms to advance shareholder interests by leading in the establishment of the market, to build skills to manage trading, and to position the company to benefit if future U.S. legislation provides credit for taking early action.

The CCX, along with the investment firm Cantor Fitzgerald, sponsor the Emissions Marketing Association (EMA). The EMA provides a newsletter, "The Emissions Trader," and up-to-the-minute data on trading prices for different gases. Figure 2 shows a discussion draft from an EMA web site article outlining the worldwide structure, greenhouse gas focus, and relationships to international trade (by way of the North American Free Trade Alliance). Taken together, the draft indicates that a very large scale and sophisticated market is on the horizon.

Voluntary "banking." Another development in the United States is by way of Section 1605(b) of the Energy Policy Act of 1992. Section 1605(b) establishes a program for voluntary reporting by businesses of greenhouse gas emissions (carbon dioxide, methane, nitrous oxide, halogenated substances, and other radiatively enhancing gases). Reporting businesses include utilities, manufacturers, coal producers, chemical companies, information technology firms, and trade associations reporting on behalf of members. Companies report baseline emissions and emissions reductions for various periods, and the information is posted on a publicly accessible database. While the enabling legislation does not provide motives for participation, the Department of Energy (DoE) points out that reasons companies may participate include, in addition to demonstrating progress in reducing emissions, the opportunity to gain recognition for environmental stewardship and to exchange information about ways to cut back emissions.[22] The DoE also cites another reason—to post information as "reference for future consideration"—a rationale which many observers interpret as a harbinger of a future market in which credits for

[22] See U.S. Department of Energy, Energy Information Administration, "Voluntary Reporting of Greenhouse Gases Program Brochure" at http://www.eia.doe.gov/oiaf/1605/Brochure.html (accessed May 2005).

emissions would be granted and made transferable or exchangeable among companies.[23] In 2002, in reference to Section 1605(b), President Bush directed the DoE to "recommend reforms to ensure that businesses and individuals that register reductions are not penalized under a future climate policy and to give transferable credits to companies that can show real emissions reductions." These directions stop short of directing market-like exchange, although the DoE guidelines to implement the president's directions still are in draft form. (The public comment period for the guidelines closed in late June 2005.)

Weather contracts. Companies and individuals can hedge against the risk caused by unexpected weather conditions by trading.[24] Since 1999, the Chicago Mercantile Exchange has offered trading of futures and options contracts on the average temperatures of many U.S. cities. In 2003 and 2004, the exchange began to offer weather contracts on European and Asian cities. The Intercontinental Exchange and the London International Financial Futures and Options Exchange also offer trading. The products are standardized contracts traded publicly on the open market in an electronic auction-like setting with continuous negotiation of prices.[25] Market participants include energy producers and consumers, beverage producers, builders and building material suppliers, ski resorts, road salt companies, and municipal governments, as well as insurers and reinsurers, investment banks, and hedge funds. Contracts can be written on temperature, rainfall, snow, wind speed, and humidity and can have terms from a week to several years. For example, a major energy-using company can hedge the risk associated with lower-than-average winter temperatures by buying a temperature contract specified for the winter season.

Valuation of Other Nonmarketed Goods and Services

The examples above show the response of private markets to the valuation of environmental conditions in trading regimes. The valuation of other kinds of environmental

[23] For example, see "Comments by The Pew Center on Global Climate Change Regarding General Guidelines for Voluntary Greenhouse Gas Reporting: Proposed Rule," February 11, 2004, at http://www.pewclimate.org/policy_center/analyses/ghg__reporting.cfm?printVersion=1 (accessed May 2005) and "Bush Administration's Proposed New Rules for Voluntary Greenhouse Gas Reporting Raise Many Questions," *The Emissions Trader*, vol. 8, no. 1, February at http://www.emissions.org/publications/emissions_trader/0402/ (accessed May 2005).

[24] Zing, 2000 and Cao and Wei, 2000 discuss how these markets work. A good overview of the current market is at http://www.climetrix.com/WeatherMarketOverview/default.asp (accessed May 2005).

[25] Over-the-counter (OTC) weather derivatives are privately negotiated, individualized agreements made between two parties.

conditions can be more complex, particularly in the case of public goods which, unlike a company's own emissions, lack private ownership. Parks, wilderness areas, and ecosystems, for instance, come without price tags and without incentives for trading exchanges.

Nonetheless, some five decades of research into the valuation of nonmarketed goods and services has made use of the fact that people make choices related to nonmarketed assets and that value can be inferred from these choices. For example, people spend more to live in a scenic area and spend money to travel to parks and beaches. Researchers have developed and tested statistical methods to derive estimates of values from these actions. Another variation of this approach is the use of detailed surveys designed to elicit honest statements about preferences and values placed on nonmarketed goods and services. The survey method is known as contingent valuation because it asks people to state willingness to pay conditional on a variety of factors, including the possibility of actually having to pay the revealed amount (thus, discouraging respondents from overstating preferences or "free riding").[26] Researchers also have extended the survey method to situations in which people value a resource that they may not presently or may never use. For example, people may want the Grand Canyon to be preserved even if they never plan to visit it.[27]

These approaches are not without methodological and empirical issues that remain the domain of researchers, and the approaches also are controversial in application.[28] Nonetheless, these approaches are now on record as methods admitted by courts (for example, in adjudicating damages in the Valdez oil spill, many parties to the dispute employed various of these approaches) and by government agencies, including the Department of Interior, the National Oceanic and Atmospheric Administration, the Army Corps of Engineers, the Department of Agriculture, and the Environmental Protection Agency (EPA). Federal law, such as the Deepwater Port Act of 1974 and the Clean Water Act amendments of 1977, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, the Oil Pollution Act of 1990, and the National Marine Sanctuaries Act of 1972, also call for natural resource damage assessment in establishing liability for injury to natural resources. The U.S. Office of Management and Budget (OMB) (1996) cites these approaches as among best practices for

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[26] Mitchell and Carson (1989), Freeman (1993), and Kopp and Smith (1993), provide substantial background about methods, issues, and application of these approaches to valuation of nonmarket goods and services.

[27] Freeman (1993) discusses "nonuse" or "intrinsic" values in chapter 5; see also Kopp and Smith (1993).

[28] Kopp and Smith (1993) offer excellent discussion of these issues and controversies.

agencies to use in assigning value to nonmarket goods and services, including environmental goods and services, in its formal guidelines for regulatory evaluation.

In spite of these practices, and despite the growing sophistication of valuation methods, they are still met with significant skepticism in public discussion. A competing alternative to valuation of ecosystems, in part because of the inherent methodological and philosophical issues associated with valuation, is the development of environmental indicators.[29] Proponents of indicators argue that these quantitative (but not monetarily denominated) rankings can inform decisionmakers in setting priorities. Moreover, proponents point out that indicator methodologies make explicit interrelationships within ecosystems (pertaining to water, land, and the atmosphere, for instance) whereas valuation techniques may overlook these.

Indicators can be developed for ecosystems such as coasts and oceans, farmlands, forests, fresh waters, grasslands and scrublands, and urban and suburban areas or for specific species, fishing stocks, and other resources. Indicators typically measure features such as size, vegetation, boundaries, and function (in absorption, for example). In addition to biophysical assessment, indicators also can define and rank the services provided by ecosystems. For instance, ecosystems can purify air and water, reduce flood risks, influence farming output, and provide recreation. It's largely on the basis of these services (rather than the health of the ecosystems themselves) that indicators provide an alternative to valuation techniques. For instance, Boyd and Wainger (2003) point out that even if an ecosystem rates highly in terms of its functional characteristics, the function may not provide a socially valuable service. Wetlands with an equivalent ability to clean groundwater or absorb floodwater may differ in their social value in terms of the number of people whose drinking water is purified and the number of homes protected from flooding. Boyd and Wainger (2003) acknowledge that the notion of service value is anthropocentric but argue that is the best practical means of differentiating among ecosystems when making trade-offs.[30]

Table 2, from Boyd and Wainger (2003), shows one of sixty environmental indicators developed in a case study for wetland mitigation in Lee County, Florida. A developer agreed to restore wetlands on Little Pine Island in return for the right to sell wetland mitigation credits to

[29] For a recent and very detailed set of examples, see Boyd and Wainger (2003). Boyd (2004) compares indicators with monetary valuation approaches.

[30] Boyd and Wainger (2003, p. 5 and note 14).

individuals wishing to develop wetlands elsewhere in the region. The indicators constructed in the case study are intended to illustrate for decisionmakers the way in which relocation of wetland functions affects a host of benefits associated with wetlands. Boyd and Wainger (2003) conclude that the indicators inform planners of tradeoffs associated with different parcels of land but that the indicators are not "the full story" because they don't reveal inherent relative values placed by citizens among the many different benefits.

Current applications of indicators include some use in managing wetlands under the Clean Water Act by which wetland mitigation projects often involve the exchange of one wetland for another (as illustrated in Boyd and Wainger's case study); agriculture support programs involving development of farmland in the Conservation Reserve Program; and the exchange of federal and nonfederal land under the Federal Land Management Policy Act.

Current applications of indicator methods typically focus only on biophysical measurements rather than service assessment. An indicator can be in the form of a color-coded map of an ecosystem delineating land use, soil conditions, and aquifer boundaries, for example, or, as in Table 2, it can be in the form of a matrix of numbers indexed to range from high to low and assessing in detail dimensions of a site (number of rare species, atmospheric conditions, etc.). Decisionmakers and existing policy often stop short of advocating or requiring service assessment, however, just as they may stop short of valuation. Moreover, data availability and quality in spatial and temporal dimensions often are lacking, much as data is a shortcoming in valuation methods.[31] However, the tools of geographic information systems (GIS) have radically advanced data collection for indicator measurement and the specification of interdependencies within an ecosystem. Particularly in the past couple of years, more capable and affordable GIS has allowed increasingly detailed and better calibrated data to show these features. The spatial view also provides perspective on the accessibility of a site for recreation or proposed development—a good metaphor is that GIS provides a much more complete landscape of ecosystem relationships.[32]

[31] Heinz 2002.

[32] Boyd and Wainger 2003.

2.2.2 Valuing Life

Valuation of ecosystems by way of financial or even indicator measures is controversial, but the challenges are overshadowed by the contentiousness of valuation of life. Much of the justification for government rulemaking in the areas of occupational safety, public safety (transportation, products and services), public health, and environmental management rests on estimates of the benefits to society of reduced mortality rates. Studies of how to measure the value of these rates date from the early 1970s (the invention is credited to a 1970 article by S. Fanshel and J.W. Bush; see Adler 2005, note 2). Advocates point out that even if assigning monetary value to life is uncomfortable—and even if most people say that they will spare no expense to avoid a potentially fatal risk—individuals implicitly act on the contrary. In other words, we jay walk, run red lights, speed, don't use seatbelts, and often don't ask passengers in our cars to use seatbelts. These actions indicate that we are willing to accept some risk in exchange for saving time or money and avoiding inconvenience.[33]

A large literature dating from the 1970s discusses methodology and results for estimating the value of a statistical life (VSL). According to one researcher, "literally hundreds of health care cost-effectiveness studies are now published in academic journals every year."[34] The "statistical life" part of the VSL framework is key. The concept focuses not on moral, ethical, religious, or cultural measures of the value of life. Rather, the concept represents a measure of the observed price of fatality risks (Viscusi 1992). The concept is based on the observation that a 1 in 100,000 risk of death to an individual is equivalent in statistical terms to one death in a society or community of 100,000 people. What the community is willing to pay collectively to reduce deaths in the community by one is a measure of the value that society places on one life or one "statistical" life. The amount a community of 100,000 is willing to pay in aggregate for a reduction in deaths by one is equal to what a typical person in the community is willing to pay for a 1-in-100,000 reduction in the risk of individual death, multiplied by the number of people in the community or 100,000. For example, if each person in the community is willing to pay $50 for a 1-in-100,000 reduction in individual death risk, then the value of a statistical life in this community is $50 times 100,000 or $5 million.

[33] Brannon (2004–2005) develops this argument.

[34] Adler (2005, p. 3). Not all of these studies use a dollar-denominated value; they often use one of the other measures discussed next in this section and without applying the dollar multiplier.

The VSL is a reflection of individual willingness to pay for a very small reduction in a very small risk of death. A $5 million VSL does not imply that an individual would be willing to accept certain death for $5 million or a 0.50 increase in individual death risk for a payment of $2.5 million. For the same reason, the VSL can differ from a person's total lifetime earnings potential.

Estimating the VSL

Estimates of the VSL typically are derived from among three hypotheses related to individuals' willingness to pay for reductions in fatality risks. One hypothesis is that willingness to pay shows up in labor market data, specifically in the wage premiums associated with higher risk jobs after adjusting for differences in the age and health status of workers. A second perspective looks at averting behavior—the actions individuals take to avoid risk, such as paying extra for optional safety features in autos. A third approach uses carefully designed surveys of individuals in which they are asked how much they are willing to pay to avoid early risk of death in a variety of scenarios. For example, the subject answers questions such as "would you accept $1,000 to accept a higher risk of death—moving from 1 in 10,000 to a 5 in 10,000 chance of death?" The amounts offered decrease until the subject refuses money for the risk.

The first two approaches are known as revealed preference studies, and the survey approach is known as stated preference (contingent valuation) studies. Each approach has advantages and disadvantages in concept as well as in statistical formulation. For instance, wage premiums are based on perceived risk rather than actual risk. In averting behavior, comparing purchases of antilock brakes and on-board safety navigation systems may fail to take into account other attributes of these devices, such as possible convenience benefits of on-board navigation. In the case of contingent valuation, questions are hypothetical and often elicit "protest" votes in which respondents are not willing to accept any amount for increases in risk. These problems complicate statistical modeling. And all three methods are hampered by imperfect data.

In practice, a policymaker might choose from among the range of estimates derived from all of the approaches; the official EPA VSL is based on 26 studies, of which 21 are labor market studies and five are stated preference studies (at the time of the agency's decision, studies based on the second approach, averting actions, had not yet been conducted).[35] The studies were

[35] Dockins et al. 2004.

originally assembled in the late 1990s for EPA's assessment of the Clean Air Act. The original estimates ranged from $0.9 million to $20.9 million (2002 dollars) and are from studies conducted between 1976 and 1991. Recently, the EPA has sponsored several meta-analyses that encompass a number of existing studies to find an average value.[36] However, EPA also has expressed concern that the approach requires a great deal of similarity among the constituent studies to avoid an "apples to oranges" comparison.

Several different concepts for measuring the VSL are currently at the forefront of debate (in addition to debate over the concept of VSL itself). At present, standard practice at EPA and the Food and Drug Administration, for instance, is to use an age-invariant VSL on the order of $6 million (within each agency, different offices have used different VSLs, but they have tended to be roughly this size). However, two additional measures also are a topic of current debate: an age-adjusted value called a value of statistical life year (VSLY) and a quality-adjusted life year (QALY).

Value of statistical life year. The VSLY takes age into account. It adjusts the VSL by discounting life-years saved in the future. Perhaps most recently notable in this regard is the February 2003 uproar over actions by EPA.[37] In a legislative proposal to reduce power plant emissions, EPA suggested that the economic value of saving the elderly from premature death caused by air pollution was less than that of saving healthy younger adults. In the cost–benefit analyses for the rule, known as the "Clear Skies" Initiative, a base case without the "senior discount" resulted in benefits of $93 billion. In an alternative case with the discount, the benefits were $11 billion. The estimated cost of the program was about $6 billion. Accordingly, both the concept (older age matters less) and the large difference in results ($93 billion compared with $11 billion for a program costing $6 billion) sparked controversy. Advocacy groups, religious organizations, and other opponents harshly criticized EPA, and the agency subsequently withdrew the alternative analysis in May.[38]

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[36] See Dockins et al. (2004). This paper, prepared by EPA for presentation to its external Science Advisory Board in 2004, gives details on the background of EPA's VSL and contains 10 detailed appendices of recent VSL studies, as well as a detailed reference list of the newest VSL studies.

[37] See Schmidt 2003.

[38] The EPA used an age-adjusted VSL figure ($3.7 million for deaths of individuals under 70; $2.3 million for deaths of individuals over 70; see EPA, Technical Addendum: Methodologies for the Benefit Analysis of the Clear Skies Initiative, September 2002, pp. 35–37). Senior citizen groups protested and the OMB issued a memorandum instructing EPA and other agencies not to use age-adjusted VSL (see John D. Graham, Memorandum to the President's Management Council 1, May 30, 2003, and OMB Circular A-4, Sept. 17, 2003, p. 30).

Quality-adjusted life year. The QALY approach attempts to take into account the quantity and the quality of life. The QALY relates additional years of living in perfect health compared with living with health problems. The concept is that one year of life at less than full health can be considered equivalent to less than one year of life in full health. A year of life in full health is given a QALY of 1.0, a year of life at less than full health is given a QALY between 0.0 and 1.0, and death has a QALY value of 0.0. For instance, in the literature on QALYs, saving the life of a person with a chronic health condition is less valuable than saving the life of a person in good health. QALY values typically are derived from surveys of individuals from a relevant population and are the individuals' subjective, personal judgments. QALYs are therefore reflective of the population on which they are defined. In addition, a one QALY gain to a young person is considered equivalent to a one QALY gain to an older person. For use in cost–benefit studies, the QALY measure often is then converted to dollars by multiplying by an estimated dollar amount of the value of life.

Using value-of-life concepts in policymaking has a long but controversial history, even though their use has increased in recent years. In 1990, in one of the first applications of the concept, Oregon used, and then abandoned, QALYs in deciding Medicaid coverage. Since then, the Food and Drug Administration has used QALYs over the last half decade or so in pharmaceutical licensure decisions and in other decisions uses a VSL of about $5 million. The Occupational Safety and Health Administration uses some of these measures in regulating toxins, the Department of Health and Human Services uses them in policies about Medicare coverage, and the Department of Transportation uses VSL in safety regulation. Although EPA has used the concepts for some rulemakings, the agency specifically has declined to use them in others. The measures are more widely used in other countries such as Australia and Canada, which regularly apply them in determining the cost-effectiveness of pharmaceuticals proposed for public reimbursement.

Among the problems that are now prominent in discussion of VSL measures are those that pertain to extrapolation of VSL in time and geographic space. Most of the early literature estimated the value that healthy, prime-aged adults place on reducing their risk of dying. Yet some researchers point out that according to epidemiological studies, the majority of statistical lives saved by environmental programs appear to be the lives of older people and people with chronically impaired health. As a result, recent studies have focused on additional factors, such as effects of age, baseline health, latency of illness, and voluntariness of ill health as influences on willingness to pay for mortality risk reductions.[39] There is some weak statistical support that VSL declines with age, but only after 70, and in this particular study (Dockins, 2004), the decline is seen in Canada but not the United States.[40] There also is some evidence that people with some chronic illnesses are willing to pay as much or more than people without these illnesses to reduce their risk of dying.[41] In another study of whether latency matters in influencing peoples' VSL and based on discount rates implied by survey data, results suggest that delaying the time at which a reduction in risk occurs can significantly reduce willingness to pay.[42] Finally, some studies using surveys from the United Kingdom and Canada have found that seniors would pay approximately 35% less for risk reduction than would healthy adults, although subsequent studies have not been able to replicate all of these findings.[43]

More recent studies dating from 2002 to the present and using various methods (new methods applied to old data as well as to new data) suggest the VSL may range between $2 million to $16.4 million.[44] The large range makes it difficult for policymakers to "pick." And critics of the VSL concept continue to press their case that VSL is flawed, while others point to the public's lack of comfort with the assignment of monetary values to life. OMB has proposed an additional approach that uses QALYs without monetary valuation and notes that they could be used in conjunction with valuation (see OMB Circular A-4, September 17, 2003, p. 9). Meanwhile, EPA is seeking advice from its external Science Advisory Board and others as the agency considers whether to revise and update its VSL guidelines.[45]

The application of value-of-life measures to the three examples of lightning, climate change, and severe weather involve all of the complications inherent in these measures. Yet, they also offer a benchmark against which to judge the extent to which protection and warning can figure in managing a response to a forecast of lightning or severe weather. In the case of climate change, the issues also loom large. Of key concern is discounting to adjust for effects that may

[39] Dockins et al. (2004), and for additional concerns, Brannon (2004–2005).

[40] Alberini et al. 2004a.

[41] Alberini et al. 2004a.

[42] Alberini et al. 2004b.

[43] Schmidt 2003.

[44] See the studies summarized in Dockins et al. (2004).

[45] See Dockins et al. (2004).

occur in the long run and whether and if so, how, to account for differences in aggregating benefits and costs that occur in different parts of the world.[46] In the mid-1990s, some researchers involved in the Intergovernmental Panel on Climate Change process brought value-of-life estimates into draft chapters on the social costs of climate change. A widespread and widely reported controversy immediately resulted. Criticized, in particular, were the draft's use of U.S.-based estimates and a proposal to assign different values to an industrialized life and a non-industrialized life.[47]

2.3.3 Accounting for the Future

As noted, some of the valuation measures described above involve discounting. It is quite often the case in considering environmental phenomena that monetary and nonmonetary costs and benefits are not exclusively associated with the present day. The temporal dimension is complex in many cases, often with costs incurred today and benefits occurring tomorrow (for example, in the case of actions taken now to mitigate or adapt to climate change, or investments made now in lightning safety in the expectation of benefits in the future). The accounting adjustment typically is the procedure of discounting, although both the theory and the practice can be complicated and contentious.

The formal discounting procedure usually starts with market interest rates, which themselves have long been a research topic.[48] Choosing a rate is far from clear. Some argue that if the discounting involves a government-funded public activity, which is typical for many environmental activities, then the rate should reflect the rate at which government can borrow, as compared with the rate at which individuals can borrow.

The choice of a rate can tip the balance in cost–benefit studies. For instance, for long-lived projects, the benefits can look favorable at a 3% rate but not so at a 5% or 10% rate. For projects that are extremely long-lived (perhaps some climate investments; certainly investments

[46] See U.S. Congress (2005).

[47] See Consortium for International Earth Science Information Network (1995).

[48] Market interest rates are said to reflect at least three interrelated dimensions of people's preferences: the extent to which they simply prefer money today to money tomorrow in a purely risk-free world; their risk aversion when the world is not risk-free; and the rate of inflation. Additional complications are taxes and imperfections in the markets for money.

in the management of nuclear waste or inorganics associated with Superfund sites), benefits or costs may occur so far into the future that discounting becomes meaningless. For instance, innovation can take place over time. The argument can be made that future generations will be as innovative if not more so than the present generation in addressing climate change. If this is the case, then preserving options and encouraging R&D (through tax credits and other mechanisms) is important. In addition, as demonstrated in the wake of the Exxon Valdez oil spill, natural processes also can contribute to recovery of resources (see Kopp and Smith 1993, p. 318).

The relevance of discounting extends to at least three decisions facing policymakers: it is a major determinant of whether a project has positive net benefits (that is, whether the investment should be made); it is a major determinant of the relative value of competing projects or investments (say, the mix of mitigation and adaptation); and it is a major determinant of the optimal timing of the project (should it be undertaken now or should it be postponed).[49] Beginning in 1972, the OMB recommended that federal agencies use a common discount rate in project evaluation (previously agencies could use any rate). Current guidelines suggest a range of rates and request that agencies use this range of rates to demonstrate the sensitivity of the project's economics to different rates. However, choice of the range remains controversial and age-old issues have risen to the fore with current discussion of climate change.

3. Summary

How safe is safe enough, as framed by arguments over the precautionary principle, together with how best to quantify risk if a policy objective is to accept some rather than no risk, have long been the subject of academic study. Application of these concepts in practice compounds their methodological challenges. Whether the environmental risk is lightning, a changing climate, or anticipating severe weather, taking action uses resources, and resources are limited. And, much like the difficulty of communicating the probability of these risks, communicating important nuances about the value of a statistical life as a means of bounding the size of resources at stake also is problematic. The point of this paper has been to emphasize that the current generation of decisionmakers is revisiting these issues. Not only are these topics now

[49] The collection of papers in Lind et al. (1982), illustrates discounting issues specifically with respect to risk in energy policy and has long been a valuable "how to" reference. See also chapter 4, on discounting in the case of climate change investments, in U.S. Congress (2005).

prominent in public discussion, but they are likely to continue as key concerns in the coming decades. At the same time, further developments in private-sector initiatives in the case of property valuation in the form of climate exchanges and weather contracts also are likely, both enriching and expanding the opportunities for creative accommodation of environmental risk.

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Tables and Figures

Table 1. The Standard Decision Table

	No Advance Action Taken	**Advance Action Taken**
Event Happens	Losses	Avoided losses
Event Does Not Happen	No losses	Losses

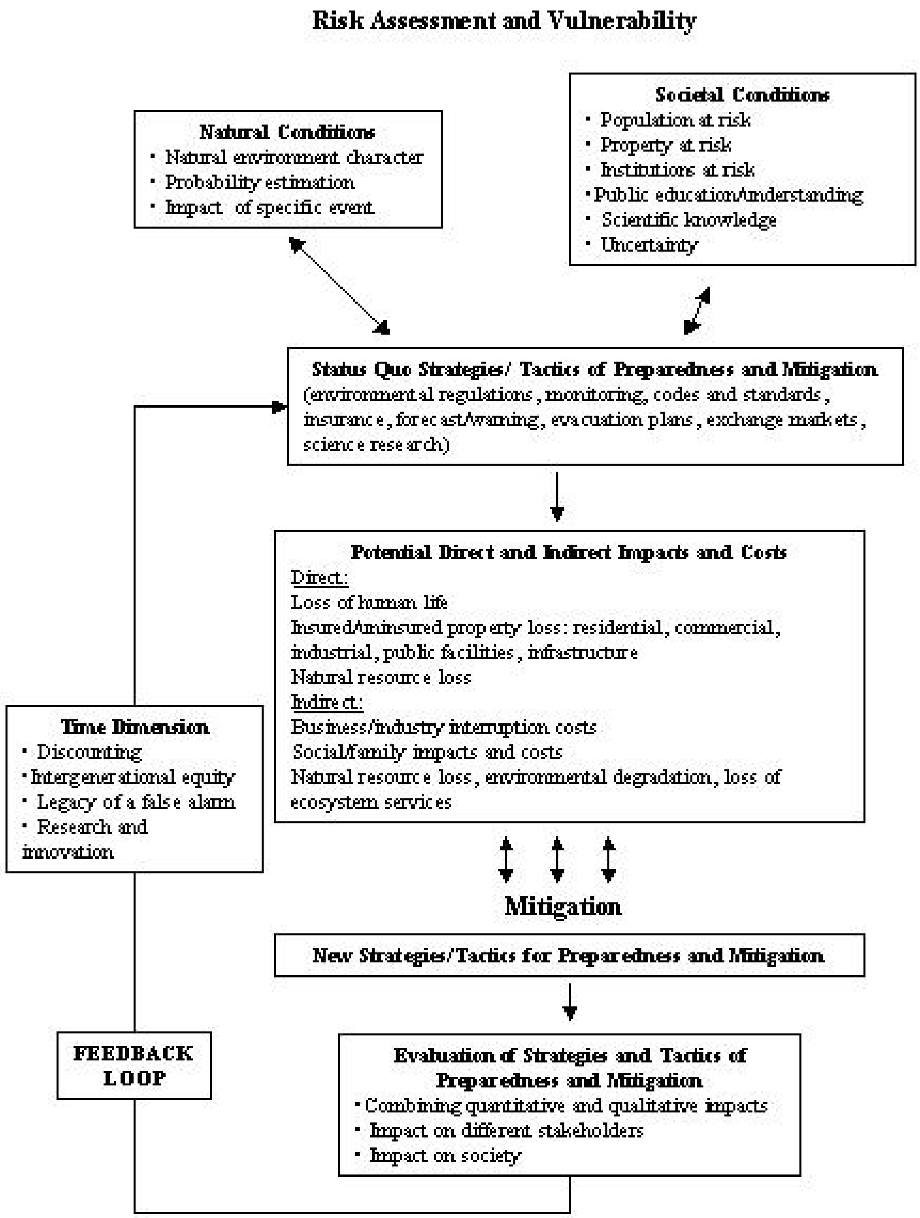

Figure 1: Risk and Cost Assessment Framework
Source: Macauley, based on Figure ES.1 in Heinz Center, 2000

Figure 1. Risk and Cost Assessment Framework

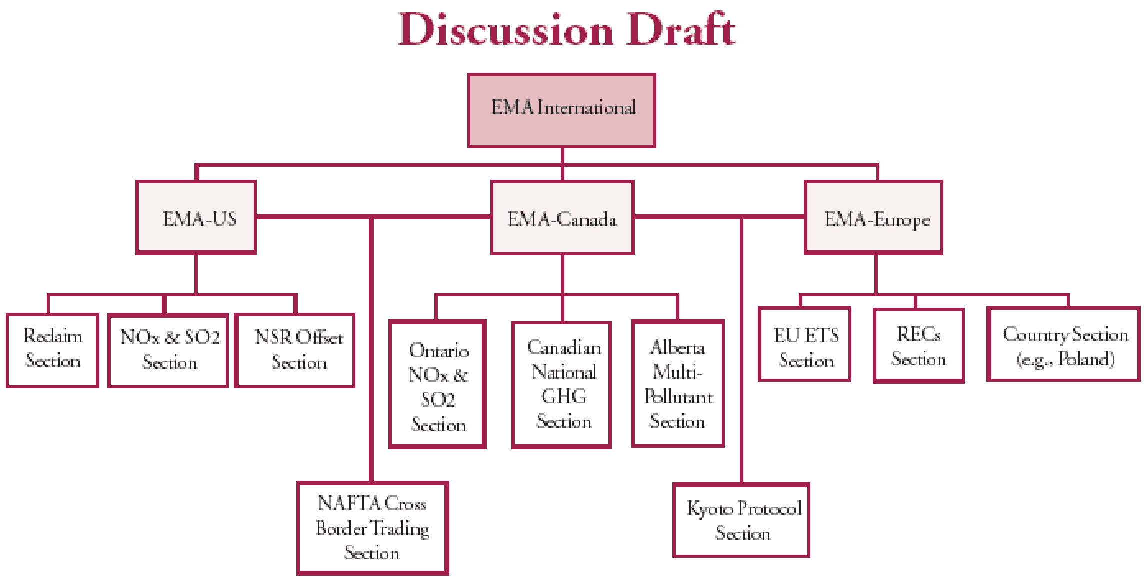

Figure 2. Illustration of Breadth of Emissions Trading

Table 2. Example of Environmental Indicators for Case Study of Little Pine Island, Florida: Relative Wetland Scarcity

Site	% Wetland in Vicinity	% Wetland in Watershed	% Watershed in Non-Agricultural Natural Land Use
1	0	8	20
2	65	36	60
3	87	8	20
4	17	36	60
6	0	8	20
7	0	16	37
8	60	36	60
9	0	34	72
10	85	8	20
LPI	78	91	100

Source: Boyd and Wainger, 2003, table 6, p. 90 (site 5 omitted in original table)