Volume Title: Measuring and Managing Federal Financial Risk

Volume Author/Editor: Deborah Lucas, editor

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-49658-9

Volume URL: http://www.nber.org/books/luca07-1

Conference Date: February 8-9, 2007

Publication Date: February 2010

Chapter Title: Environment and Energy: Catastrophic Liabilities from Nuclear Power Plants

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Chapter URL: http://www.nber.org/chapters/c3037

Chapter pages in book: (235 - 257)

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Environment and Energy
Catastrophic Liabilities from Nuclear Power Plants

Geoffrey Heal and Howard Kunreuther

9.1 Introduction

Through a comprehensive system of preparedness, protection, response, and recovery administered by the Federal Emergency Management Agency (FEMA), the Federal Government has responsibility for reducing risks and aiding the recovery of natural disasters, acts of terrorism, and other man-made disasters. The manner in which public sector organizations manage the natural environment can affect the risks that government will ultimately face. Some possible liabilities of the Federal Government are associated with environmental risks, many of which are linked to climate change. For example, the potential for global warming depends on what we do with our energy systems. Moreover, the way the Federal Government manages many environmental processes can affect our vulnerability to a range of natural disasters, not just those associated with climate change.

One source of energy that is now being seriously considered for addressing the climate change issue is nuclear power. Since the accident at the Three Mile Island nuclear power plant in Middletown, Pennsylvania in March 1979, there has not been a single nuclear power plant constructed in the United States. However, James Rogers, CEO of Duke Energy, said in 2007 that nuclear power "is still the best way to produce electricity with zero greenhouse gases from the actual operation"—even compared with energy

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We are grateful to Carol Heller, Debbie Lucas, Billy Pizer, and two referees for valuable comments on an earlier draft of the chapter. Financial support from the Wharton Risk Management and Decision Processes Center is gratefully acknowledged.

sources such as wind. The Congressional Budget Office (CBO) estimated in May 2008 that a carbon price of between $20 and $45 per ton—which many projections say is feasible—would make nuclear competitive with coal (Johnson 2008). We therefore include the risks associated with nuclear power in our analysis.

We begin with an overview of the economic value of environmental systems in mitigating natural disasters and then consider the role of the Federal Government in managing these hazards and the potential liabilities that they may incur should there be a catastrophic disaster. In the second part of the chapter we focus on nuclear power as a source of energy and ask whether the risks associated with this technology could be managed more efficiently by private insurance markets rather than through the current arrangements under the Price-Anderson (P-A) Act. As we demonstrate, the P-A Act imposes significant liabilities on the Federal Government should there be large-scale losses from a future accident at a nuclear power plant. To gain insights into an increased role for the private sector in managing this technology, programs by which other catastrophic risks are managed today are reviewed in the concluding portion of the chapter.

9.2 Natural Capital as an Asset

A nation's environmental assets are diverse and important. Environmental economists talk about natural capital on a par with physical, human, intellectual, and other forms of capital.[1] Environmental assets, like any other assets, provide a flow of services over time. Often they provide these services over very long periods of time, periods that are orders of magnitude greater than those relevant for most other forms of capital. If we value these assets at the present value of their services, then by applying conventional discount rates we lose most of the contributions that they make.

A good example is the New York City watershed, a collection of naturally-occurring ecosystems in the Catskills that cleanse and stabilize the flow of water to New York, and if not disturbed can continue to do so for centuries. Recently, the city spent over $1 billion restoring the ecological integrity of this watershed, in order to restore the city's water to earlier levels of purity. We can see this as an investment in natural capital, with the benefit being the flow of clean water and the avoidance of a complex and expensive filtration plant costing over $8 billion.[2] Although the Catskills watershed is an asset to New York City, which has invested extensively in it, the city does not own it. The watershed consists of land in the Catskills, most of which is privately owned either as farms or as homes. Today the city provides financial incen-

1. For a discussion see Barbier and Heal (2006) and the references there.
2. For more details see Heal (2000) and National Research Council (2004). For a detailed study of all aspects, economic and scientific, see also National Research Council (2000).

tives for people living and working in the watershed area to behave in ways that are consistent with the continued operation of the watershed, such as paying for farm fences to be set back from stream boundaries to keep animals well away from streams.

Natural resources such as oil, gas, coal, and various other mineral deposits are also a form of natural capital, and the values of these are often reflected in the valuations of their owners, usually corporations. It is generally recognized that one of the main determinants of the stock market value of an oil company is the value of its oil reserves.[3] An interesting point is that if a corporation depletes its oil reserves, then under US GAAP[4] and most equivalents, it must record this as depletion of assets in its financial statements. If, however, a nation depletes its reserves of oil or any other mineral resource, then the United Nations System of National Accounts does not require that it record a depletion charge against its income. If the national accounts of oil-producing countries were to record depletion charges, then their incomes would drop very significantly indeed.[5]

The climate system as well can also be viewed as an asset to the extent that it may induce individuals to reside in specific areas. Florida's climate goes a long way to explaining why people choose to live there, and some of the economic value that it generates is reflected in land values. Climate also plays an important role in determining agricultural productivity. The climate system is more than the temperature, though that is a central part of it: the humidity, precipitation, and wind patterns all impact on the economic value of specific areas.

Today, we are seeing that changes in the world's climate system, combined with increasing assets at risk, is threatening this value. For example, the population of Florida has increased significantly over the past fifty years: 2.8 million inhabitants in 1950, 6.8 million in 1970, 13 million in 1990, and a projected 19.3 million population in 2010 (almost a 600 percent increase since 1950) (Kunreuther and Michel-Kerjan 2007). The increase in the exposed property values in risk-prone areas due to a combination of pure inflation, speculation, and rises in the standard of living increase the chance of significant insured losses from future natural disasters. If Hurricane Andrew had occurred in 2002 rather than 1992, it would have inflicted twice the economic losses, due principally to increasing development and rising asset values in Miami-Dade County and adjoining coastal areas in Florida affected by the storm (Dlugolecki 2006).

Compounding this increase in exposure is a trend for tropical storms/hurricanes and typhoons to become more intense over time due to

3. See, for example, Miller and Upton (1985).
4. Generally Accepted Accounting Principles.
5. See Heal (2007) and references therein.

global warming. Emanuel (2005) introduces an index of potential destructiveness of hurricanes based on the total dissipation power over the lifetime of the storm. The index shows a large increase in power dissipation over the past thirty years and concludes that this increase may be due to the fact that storms have become more intense, on average, and/or have survived longer at high intensity. His study also shows that the annual average storm peak wind speed over the North Atlantic and eastern and western North Pacific has increased by 50 percent over the past thirty years. Recent work by the Intergovernmental Panel on Climate Change (IPCC 2007) indicates that one of the impacts of a change in climate will be an increase in weather extremes. We are likely to witness not only more intense storms, but also more intense heat waves and drought, and more intense flooding episodes as well. The impacts are predicted to be more important in many low- and middle-income countries (Africa, South America, Asia) than in the developed world.

9.3 Environmental Liabilities

What does this tell us about environmental liabilities? Certain categories are widely recognized, such as those generated by the Superfund legislation and liabilities associated with past pollution activities. In the case of Superfund there are open questions as to who is liable because of the complexities of joint liabilities. But in general, these are the responsibilities of the private sector not the Federal Government, with the exception of Department of Defense sites, whose clean-up costs have been estimated at over $30 billion.[6]

A more prominent source of liabilities of the Federal Government arises from changes in natural capital that lead to its ceasing to provide important services, often protective services. Much natural capital has the characteristics of public goods, so that the government is normally responsible for its maintenance. A timely example is the gradual destruction of the barrier islands in the Gulf of Mexico offshore from New Orleans. Historically, these islands protected New Orleans from storm surges, mitigating the impacts of the strongest storms. Their gradual disappearance contributed to the severity of the destruction wrought by Hurricane Katrina,[7] creating liabilities for the Federal Government through the designation of the region as a Presidentially-declared disaster area. Some estimates suggest that the total cost of Hurricane Katrina is in excess of $150 billion, with a significant part being the liability of the Federal Government (Kunreuther and Michel-Kerjan 2009). This is an environmental liability because it arose in part as a predictable consequence of the degra-

6. See the Congressional Budget Office (2005) report for more details.
7. See Bourne (2004).

dation of natural capital. The 2007 Stafford Act makes the Federal Government legally liable for damages of this sort, and politically it surely is: the public expects the Federal Government to step in and offer restitution in situations such as Katrina.

Hurricane Katrina is illustrative of a class of situations where the Federal Government may incur liabilities as a result of its failure to adequately manage environmental issues. In this case, a part of the cause of the disaster was undoubtedly the changes in the topography of the area around New Orleans as a result of dredging and canalization, and the removal of barrier islands, all of which can be considered degradation of natural capital or of environmental assets. The US Army Corps of Engineers, a Federal Agency, carried out many of these changes. In addition, some argue that climate change made a contribution to the severity of Katrina, and that the Federal Government, by failing to act on this issue contributed further to the severity of the problem (Emanuel 2008). The general point here is that to the extent that degradation of natural capital leads to increased severity and frequency of natural disasters, there is an increase in Federal liability, although this is hard to quantify. The natural disasters associated with the mismanagement of natural capital could include storms, wildfires, floods, and droughts, all of which can generate liabilities in the billions.

The bottom line is that natural capital is a hugely important asset, and its maintenance, normally being a Federal responsibility, can have huge impacts on Federal liabilities. These liabilities are hard to measure, but as the de facto insurer of last resort for catastrophes, it will often pick up the check.

9.4 Nuclear Liabilities

The current resurgence of interest in nuclear power owes a lot to concerns about the environmental impacts of fossil fuels. Nuclear power is largely carbon neutral and has no significant climate impact, but it does have other risks. A move to nuclear power is replacing one kind of environmental risk by another. The Federal Government accepted liability for the lion's share of the risks from a nuclear power plant catastrophe through the passage of the Price-Anderson (P-A) Act in 1957. Nuclear power stations have a rather unique environmental profile, in that when operating as planned they produce little if any environmental damage, emitting neither gases nor pollutants of any kind. There is, however, a small chance of a very serious accident, such as a core meltdown leading to damaging pollution, as in 1986 at the Chernobyl nuclear reactor in the Ukraine. In this case, clouds of radioactive waste floated over much of the Ukraine, Belarus, Eastern and Western Europe, and Scandinavia with fatalities estimated by international agencies to be about 9,000 individuals. Core meltdowns have also occurred twice in the United States, once at the Enrico Fermi reactor in Newport, Michigan, in 1966 and again at Three Mile Island in Middletown, Pennsylvania in 1979.

It is generally believed that little or no radiation was released in either of these cases (Lochbaum 2006).

In addition to the risk of a core meltdown, nuclear power stations pose problems associated with the disposal of their radioactive wastes. Over its operating life, a nuclear power station will produce many tons of highly radioactive long-lived waste, which pose a health hazard for many centuries. Since September 11, 2001, the wastes have been recognized as a possible ingredient for a dirty bomb used in a terrorist attack. The method for disposing of radioactive wastes from nuclear power stations is highly controversial, with no country having yet implemented a coherent long-term policy. In the United States, the proposed policy is that waste will be buried at the Yucca Mountain Repository in Nevada, but this has not been implemented. In the meantime, many hundreds of tons of highly radioactive waste sit in containment tanks at the sites of commercial nuclear power stations, often poorly guarded. Were some of this to fall into the wrong hands, the costs could be immense and would be the responsibility of the Federal Government: there is a Federal liability here.

A core meltdown is generally agreed to be the most serious accident that can occur to a nuclear power station. What is the risk of this event, and what are the possible consequences? In the United States, 104 commercial reactors have been built and operated. As noted, two reactors—Enrico Fermi and Three Mile Island—have experienced core meltdowns. In addition, according to data from the Nuclear Regulatory Commission (NRC), four have been closed in excess of one year for serious failures that if not corrected could have caused core meltdowns.[8] This means that six in 104 reactors have experienced meltdowns or near-meltdowns. Normally these data are not presented as X meltdowns or near-meltdowns in Y reactors, but rather as X meltdowns or near-meltdowns per Z reactor years, a numerically much smaller risk.

All the meltdowns and most of the near-meltdowns occurred in the 1960s and 1970s, which suggests that the risks are highest early in the life cycle of a reactor design. This would be reasonable, and consistent with the idea of a learning curve associated with the management of something as complex as a nuclear power station. This may be reassuring as far as the safety of existing reactors is concerned, but disturbing when one recognizes that the currently-proposed expansion of nuclear power would be through new and as-yet untried reactor designs that are focused on reducing the (very substantial) capital costs of nuclear power stations. The Federal Government has received or expects to receive applications to build thirty-four new nuclear reactors at twenty-three sites (Wald 2008). A new generation of reactors could take us back to the top of the learning curve and into an era of risk not experienced since the 1960s and 1970s.

8. Data from the US Nuclear Regulatory Commission is available in Lochbaum 2006.

What would be the costs of a core meltdown in which, as in the Chernobyl case, radiation was released from the containment vessel? There is no general theory for such an estimate, so we focus on a specific case, the case of Indian Point, a nuclear power station owned by Entergy Corporation and situated on the Hudson River twenty-four miles north of New York City. The huge population densities in the region make an accident here particularly threatening. Nuclear fallout from the plant could reach populated areas including New York City, northern New Jersey, and Fairfield County, Connecticut. A 1982 study by Sandia National Laboratories found that a core meltdown and radiological release at one of the two operating Indian Point reactors could cause 50,000 near-term deaths from acute radiation syndrome and 14,000 long-term deaths from cancer.[9] In addition to these horrifying health impacts, the release of a cloud of radioactivity over New York City could close the city down for business for a considerable period of time.

The financial costs of such an event are clearly stunning: 64,000 deaths valued at $6 million per person alone would imply a cost of $384 billion. By contrast, insured business losses and business interruptions from the September 11 terrorist attacks were valued at $32.5 billion (Kunreuther and Michel-Kerjan 2004). A disaster at Indian Point could possibly have a more disruptive effect on activity in the New York metropolitan area than the September 11 attacks, and for a much longer period of time. Business interruption losses in the range of $50 to 100 billion are possible, in addition to the costs associated with loss of life and damage to health. It is therefore reasonable to think that the direct and indirect costs of a nuclear accident could be in the hundreds of billions of dollars. Indeed, a worst-case scenario could lead to the closure of New York City for years, as happened at Chernobyl, which is still closed over twenty-two years after the meltdown, leading to almost unthinkable costs.

9.5 The Price-Anderson Act and Nuclear Accident Insurance[10]

The Price-Anderson (P-A) Act, originally enacted by Congress in 1957, limits the liability of the nuclear industry in the event of a nuclear accident in the United States. The Act was passed in order to encourage the construction of nuclear power plants in the United States. At the same time, P-A provides a ready source of funds to compensate potential accident victims that would otherwise not be available. The Act covers large power reactors, small research and test reactors, fuel reprocessing plants, and enrichment facilities for incidents that occur through plant

9. For more details see http://www.ucsusa.org/news/press_release/new-study-predicts-up-to-44000-prompt-fatalities-and-518000-longterm-deaths-from-indian-point-terror-attack.html.

10. For more details on nuclear accident insurance see Nuclear Energy Institute (2005).

operation as well as transportation and storage of nuclear fuel and radioactive wastes. The Act is seen as central to the commercial viability of nuclear power.

The P-A Act sets up two tiers of insurance. Each utility is required to maintain the maximum amount of coverage available from the private insurance industry—currently $300 million per site. This coverage is written for nuclear power plants in the United States by the American Nuclear Insurers, a joint underwriting association or "pool" of insurance companies. If claims following an accident exceed that primary layer of insurance, all nuclear operators are obligated to pay up to $100.59 million for each reactor they operate, payable at the rate of $10 million per reactor, per year. As of February 2005, the US public currently has more than $10 billion of insurance protection in the event of a nuclear reactor incident. More than $200 million has been paid in claims and costs of litigation since the Price-Anderson Act went into effect, all of it by the insurance pools. Of this amount, approximately $71 million has been paid in claims and costs of litigation related to the 1979 accident at Three Mile Island.

As part of the Energy Policy Act of 2005, signed into law by President George W. Bush on August 8, 2005, Price-Anderson was reauthorized for the next twenty years. This is the fifth time that Congress has reauthorized the Act since it was first passed in 1957 but it is the longest extension ever granted. High prices and dwindling supplies of fossil fuels have increased interest in nuclear energy, and the long extension of P-A may increase the feasibility of investment in nuclear power plants. Although, as noted before, no nuclear power plants have been built in the United States since the Three Mile Island accident in 1979, there are now nearly three dozen applications for new reactors.[11]

9.6 Are Nuclear Power Plant Accidents an Insurable Risk?

A principal reason for the passage of the P-A Act was to protect the utilities against the possibility of a catastrophic loss from a nuclear power plant accident. Private insurers were reluctant to provide this coverage because they were uncertain about the likelihood of a severe accident (e.g., a core meltdown) and the consequences of such a disaster. In other words, it was believed at the time that protection against nuclear accidents did not satisfy the conditions for insurability of a risk by the private sector. Is this indeed correct—is it really necessary that the government should assume the liabilities associated with the P-A Act, or could we, in fact, rely on the private sector to play this role?

The conditions for insurability in the context of environmental risks have

11. See http://www.cbsnews.com/stories/2008/06/13/national/main4181049.shtml?source=RSSattr=U.S._4181049.

been examined by Freeman and Kunreuther (1997). Cummins (2006) and Litan (2006) have recently examined this issue in the context of catastrophic risks. The discussion that follows uses concepts from these papers to focus on how an insurer decides whether or not to provide coverage against damage from an environmental risk.

9.6.1 Law of Large Numbers

Insurers are likely to be concerned about the variability of profits from the risks they insure. The ideal risk is one where the potential loss from each insured is relatively small and independent of the losses from other policyholders. As the insurer increases the number of policies it issues in a year, the variance in its annual losses decreases. In other words, the law of large numbers makes it highly unlikely that the insurer will suffer an extremely large loss relative to the premiums collected.

Insurance against underground storage tank (UST) leaks is an example of an environmental risk that satisfies the law of large numbers since losses are normally independent of one another. To illustrate the application of this law, suppose that an insurer wants to determine the estimated loss for a group of identical USTs, each of which has a 1/100 annual chance of leaking and causing damage of $100,000. The expected annual loss for each UST would be $1,000 (i.e., 1/100 × $100,000). As the number of UST policies n increases, then the variance of the expected annual loss decreases in proportion to n. Cummins (2006) considers the case where the insurer is willing to accept a low probability of insolvency ε arising out of a catastrophic loss when insuring a book of business. He shows that for risks that are independent and whose losses are characterized by the normal distribution so that the central limit theorem applies, the equity capital per policy approaches zero as the number of insured policies becomes very large.

9.6.2 Conditions for Insurability

The application of the law of large numbers is predicated on the ability of insurers to estimate the likelihood and consequences of a risk and for the risks to be independent of each other. The risks associated with large-scale catastrophic disasters or accidents are unlikely to satisfy the law of large numbers. The following three conditions can then determine the degree to which such a risk is insurable.

Condition 1 is the ability to identify and quantify the chances of the event occurring and the resulting losses under different levels of insurance coverage. *Condition 2* is the ability to set premiums for each potential customer or class of customers that reflect the risk. *Condition 3* is the ability to make a positive expected profit by providing coverage against the risk. We now examine each condition and raise some questions related to the ability of private insurers to provide coverage.

Condition 1: Identifying the Risk

To satisfy this condition, estimates must be made of the frequency at which specific events occur and the magnitude of the loss. The risk of a leaky UST is one with which the insurance industry is relatively comfortable because there is past data and scientific information that enables them to determine both the likelihood and consequences of such an event. Due to the infrequency of nuclear power plant accidents, it is much more difficult to estimate these parameters for insurance against this risk.

Condition 2: Setting Premiums that Reflect the Risk

Once the risk has been identified, insurers need to determine a premium that reflects the risk while not posing an unacceptably high chance of insolvency or severe loss of surplus due to a catastrophic loss. There are several factors that determine what premiums insurers would like to charge.

Ambiguity of Risk A risk is ambiguous if one cannot assign a probability to it. Insurers (and indeed, decision makers in general) dislike ambiguity. The greater the ambiguity of a specific loss the higher the premium will be. In a mail survey of professional actuaries conducted by the Casualty Actuarial Society, 463 respondents indicated how much they would charge to cover losses against a defective product in two cases, one where the probabilities of a loss (p) was well specified at $p = .001$, and one where they experienced considerable uncertainty about the likelihood of a loss with the same mean likelihood. The median premium values were five times higher for the uncertain risk than for the well-specified probability when the losses from each insurance policy were independent. This ratio increased to ten times when the losses were perfectly correlated (Hogarth and Kunreuther 1989).

In another study, a questionnaire was mailed to 190 randomly chosen insurance companies of different sizes asking underwriters to specify the prices that they would like to charge to insure a factory against property damage from a severe earthquake, to insure an underground storage tank, and to provide coverage for a neutral situation (i.e., a risk without any context). Probabilities and losses were varied. The probability of loss and the size of the claim were either well-specified or there was ambiguity regarding the likelihood of the loss and/or the claim size. The underwriters wanted to charge considerably more for the same amount of coverage when either the probability was ambiguous and/or the claim size was uncertain (Kunreuther et al. 1995).

Adverse Selection If the insurer sets a premium based on the average probability of a loss, using the entire population as a basis for this estimate, those with the highest risk will be the most likely to purchase coverage for that hazard. In an extreme case, the poor risks will be the only purchasers of coverage, and the insurer will lose money on each policy sold. This situation, referred to as adverse selection, occurs when the insurer cannot distinguish between the probabilities of a loss for good- and poor-risk categories, but the insured can.

Moral Hazard Moral hazard refers to an increase in the probability of loss caused by the behavior of the policyholder. For example, providing insurance protection to a nuclear power plant may lead the utility to behave more carelessly than if it did not have coverage. One way to avoid the problem of moral hazard is to introduce deductibles and coinsurance as part of the insurance contract. A sufficiently large deductible can act as an incentive for the insureds to continue to behave carefully after purchasing coverage because they will be forced to cover a significant portion of their loss themselves. With coinsurance, the insurer and the insured share the loss together. As with a deductible, this type of risk-sharing arrangement encourages safer behavior because those insured want to avoid having to pay for some of the losses.

Catastrophic Losses A nuclear power plant accident can produce catastrophic losses. Insurers who cover the risks from such disasters may have to pay potentially large claims to policyholders before they are able to collect sufficient premiums to cover their costs. This timing risk is an important element associated with catastrophic losses (Litan 2006). Rating agencies may also play a role in influencing how many policies an insurer will want to write on risks with respect to catastrophic losses. A recent report by the AM Best Company focuses on the importance of the ratio of annual insured catastrophic losses as percentage of policyholder surplus (PHS). In general, the report notes that the higher the level of loss relative to surplus, the greater has been the financial damage to the insurance industry (Williams and King 2006).

Condition 3: Earning a Positive Expected Profit by Marketing Coverage

In theory, insurers can offer protection against any risk that they can identify and for which they can obtain information to estimate the frequency and magnitude of potential losses as long as they have the freedom to set premiums at any level. However, due to problems of ambiguity, adverse selection, moral hazard, and highly correlated losses, they may want to charge premiums that considerably exceed the expected loss. For some risks the desired premium may be so high that there would be very little demand for coverage at that rate. In such cases, even though an insurer determines that a particular risk meets the two insurability conditions discussed previously, it will not invest the time and money to develop the product.

More specifically, the insurer must be convinced that there is sufficient demand to cover the development and marketing costs of the coverage through future premiums received. If there are regulatory restrictions that limit the price insurers can charge for certain types of coverage, then companies will not want to provide protection against these risks. In addition, if an insurer's portfolio leaves them vulnerable to the possibility of extremely large losses from a given disaster due to adverse selection, moral hazard, and/or high correlation of risks, then the insurer will want to reduce the number of policies in force for these hazards.

9.6.3 Conclusions on Insurability of Nuclear Reactors

The catastrophic risks associated with a meltdown of a reactor in a populated area, together with the release of radioactivity, are unlikely to be readily insurable. The risks are unique and massive, and not well understood. Problems of moral hazard and adverse selection may also be serious. If private insurers were to charge a premium that reflected their risk given the aforementioned features, it is likely to be considerably higher than if there was some public sector involvement. The Price-Anderson Act was passed in this spirit but has not been evaluated with respect to how well it meets society's needs. We now address this question.

9.7 Evaluating the Price-Anderson Act as an Insurance Program

Price-Anderson can provide as much as $10 billion of insurance to cover catastrophic losses. This is perhaps 10 percent of the likely cost of a meltdown associated with the release of radioactivity. The Act cannot provide adequate coverage should there be a severe nuclear accident. The gap between what is available under the Act and what would be needed would almost certainly be filled by the Federal Government. In other words, there is a potential liability by the public sector of $100 billion (or possibly much more) under the Price-Anderson Act. The probability that this liability will be incurred is small, so the expected value of the liability is perhaps in the range of billions rather than tens of billions.

9.7.1 Regulatory Capture

The risk that the government faces with respect to nuclear accidents is not entirely outside of its control. The government has to license nuclear power stations, and the NRC sets safety standards that if well enforced could cut the government's risk significantly. There is a lot of evidence that the NRC suffers from regulatory capture and has performed poorly in its role of safety overseer (Lochbaum 2006). The Federal Government can also reduce the risks associated with nuclear power by influencing the location of nuclear power points to more remote locations rather than major population centers, so as to reduce potential liabilities.

9.7.2 Subsidies Associated with Price-Anderson

Utilities are subsidized under the P-A Act because they are only responsible for damage up to about $10 billion. Canada has a similar cap on damages specified in the 1970 Nuclear Liability Act. The Canadian courts were forced to address the decreased incentive that this limited liability provides for investing in safety measures. In fact, the economist Ralph Winter, in a commentary on Ontario Hydro's behavior, pointed out that the utility is looking for alternatives to investing in safety measures because of the high costs associated with them (Heyes 2002–2003).

Another disincentive for utilities to invest in safety measures stems from the fact that insurance premiums do not reflect the performance and related risk associated with a nuclear power plant. Should there be an outage by a plant, the premiums are not adjusted upward to reflect the higher risk. By not having experience-rated premiums there is a type of interdependence that can be deleterious to all utilities in the industry. The financial vulnerability of one nuclear power plant depends not only on its own choice of security investments, but also on the actions of other agents. Inadequate investment elsewhere can raise a plant's premiums. This concept of *interdependent security* implies that outage in one plant could have financial impacts on all the other utilities operating nuclear power plants. As a result there may be suboptimal investment in the individual components (Kunreuther and Heal 2003; Heal and Kunreuther 2005). The existence of such interdependencies provides another challenge in determining the design of a nuclear power plant insurance program.

9.8 Modifying Price-Anderson

9.8.1 Learning from Other Federal and State Catastrophe Programs[12]

We now review the roles that the federal and state governments in the United States play in supplementing or replacing private insurance with respect to natural disasters and other catastrophic losses. In many respects, the problems faced in these areas are similar to those associated with nuclear accidents: they involve low-probability, high-cost risks for which the likelihoods of an accident are uncertain. Hence, there are lessons to be learned from these other areas. We shall discuss insurance against floods, hurricanes, and earthquakes as well as terrorism insurance.

Flood Insurance

Insurers have experimented over the years with providing protection against water damage from floods, hurricanes, and other storms. After the

12. The material in this subsection appears in Wharton Risk Center (2005).

severe Mississippi Floods of 1927, they concluded that the risk was too great for them to insure and refused to continue doing so. As a result, Congress created the National Flood Insurance Program (NFIP) in 1968, whereby homeowners and businesses could purchase coverage for water damage. Private insurers market the flood policies, and the premiums are deposited in a federally operated Flood Insurance Fund, which is then responsible for paying claims. The stipulation for this financial protection is that the local community makes a commitment to regulate the location and design of future floodplain construction to increase safety from flood hazards. The Federal Government established a series of building and development standards for floodplain construction to serve as minimum requirements for participation in the program. The creation of the Community Rating System in 1990 has linked mitigation measures with the price of insurance in a systematic way (Pasterick 1998).

Hurricane Insurance

The need for hurricane insurance is most pronounced in the state of Florida. Following Hurricane Andrew in 1992, nine property-casualty insurance companies became insolvent, forcing other insurers to cover these losses under Florida's State Guaranty Fund. Property insurance became more difficult to obtain as many insurers reduced their concentrations of insured property in coastal areas. During a special session of the Florida State Legislature in 1993, the Florida Hurricane Catastrophe Fund (FHCF) was created to relieve pressure on insurers to reduce their exposures to hurricane losses. The FHCF, a tax-exempt trust fund administered by the state of Florida, is financed by premiums paid by insurers that write policies on personal and commercial residential properties. The fund reimburses a portion of insurers' losses following major hurricanes (above the insurer's retention level) and enables insurers to remain solvent (Lecomte and Gahagan 1998). The four hurricanes that hit Florida in the fall of 2004 (Charley, Frances, Ivan, and Jeanne) caused an estimated $23 billion in insured losses, with only about $2.6 billion paid out by the Fund. Each hurricane was considered a distinct event, so that retention levels were applied to each storm before insurers could turn to the FHCF.

During a special session of the Florida State Legislature in January 2007, the capacity of the FHCF was expanded to $27.75 billion in insurance. However, there would have to be no damaging hurricanes until the year 2024 for the FHCF to pay all its claims from a hurricane with a 500-year return period. If such a disaster occurred before that date, the additional capacity to meet all the FHCF claims would have to come from assessing all property and casualty lines of business, excluding workers' compensation, accident and health, medical malpractice, and flood insurance (Kunreuther and Michel-Kerjan 2009).

Earthquake Insurance

The history of earthquake activity in California convinced legislators that this risk was too great to be left in the hands of private insurers alone. In 1985, a California law required insurers writing homeowners' coverage on one- to four-unit residential buildings to also offer earthquake coverage. Because rates were regulated by the state, insurers felt they were forced to offer coverage against older structures in poor condition, with rates not necessarily reflecting the risk. Following the 1994 Northridge earthquake, huge insured property losses created a surge in demand for coverage. Insurers were concerned that if they satisfied the entire demand, as they were required to do by the 1985 law, they would face an unacceptable level of risk and become insolvent following the next major earthquake. Hence, many firms decided to stop offering coverage or restricted the sale of homeowners' policies in California.

In order to keep earthquake insurance available in California, in 1996 the State legislature authorized the formation of the California Earthquake Authority (CEA), a state-run insurance company that provides earthquake coverage to homeowners. The innovative feature of this financing plan is the ability to pay for a large earthquake while committing relatively few dollars up front. There was an initial assessment of insurers of $1 billion to start the program and then contingent assessments to the insurance industry and reinsurers following a severe earthquake. Policyholders absorb the first portion of an earthquake through a 15 percent deductible on their policies (Roth 1998). However, twelve years after the creation of the CEA, the take-up rate for homeowners was about 15 percent, down from 30 percent when the California State Legislature created the CEA (Risk Management Solutions 2004). It is questionable how effective this program will be in covering losses should a major earthquake occur in California.

Federal Aviation Administration Third-Party Liability Insurance Program

Since the terrorist attacks of September 11, 2001, the US commercial aviation industry can purchase insurance for third-party liability arising out of aviation terrorism. The current mechanism operates as a pure government program, with premiums paid by airlines into the Aviation Insurance Revolving Fund managed by the Federal Aviation Administration (FAA).

As the program carries a liability limit of only $100 million, losses paid by government sources in the event of an attack will almost surely exceed those available through the current insurance regime. In that case, either the government would need to appropriate additional disaster assistance funds as it did in the aftermath of September 11, or victims would be forced to rely on traditional sources of assistance (Strauss 2005).

Terrorism Insurance

Insuring the risks from terrorist attacks has some similarity to insuring nuclear accidents—indeed, one worst-case terrorist scenario involves terrorists causing a nuclear accident. In both cases the probability distribution over possible losses is largely a matter of guesswork, with no historical record to provide a benchmark. And in both cases, government policies can influence the risks. So it is worth spending some time reviewing the extensive recent discussion of how to manage terrorist risks.

Prior to September 11, terrorism exclusions in commercial property and casualty policies in the US insurance market were extremely rare (outside of ocean marine) because losses from terrorism had historically been small and, to a large degree, uncorrelated. Attacks of a domestic origin were isolated, carried out by groups or individuals with disparate agendas. Thus the United States did not face a concerted domestic terrorism threat, as did countries such as France, Israel, Spain, and the United Kingdom.

In fact, insurance losses from terrorism were viewed as so improbable that the risk was not explicitly mentioned nor priced in any standard policy and it was never excluded from so-called "all-risk" policies with the exception of some marine cargo, aviation, and political risk policies. Even the first attack on the World Trade Center (WTC) in 1993[13] and the Oklahoma City bombing of 1995[14] were not seen as being threatening enough for insurers to consider revising their view of terrorism as a peril worth considering when pricing a commercial insurance policy. Since insurers and reinsurers felt that the likelihood of a major terrorist loss was below their threshold level of concern, they did not pay close attention to their potential losses from terrorism in the United States (Kunreuther and Pauly 2005).

Terrorism presents a set of very specific problems regarding its insurability by the private market alone that have similar features to nuclear power. These include the potential for catastrophic losses, the existence of interdependencies, and the dynamic uncertainty associated with the risk. All of these factors increase the amount of capital that insurers must hold to provide terrorism risk insurance coverage. The associated costs of holding that capital increases the premiums they would need to charge. The fact that government actions are likely to influence both the will and capacity of terrorist groups to attack (foreign policy, counterterrorism) and the level of potential losses poses additional challenges. These challenges are closely related to the fact that the Nuclear Regulatory Commission influences the

13. The 1993 bombing of the WTC killed six people and caused $725 million in insured damages. See Swiss Re (2002).

14. Prior to September 11, the Oklahoma City bombing of 1995, which killed 168 people, had been the most damaging terrorist attack on domestic soil, but the largest losses were to federal property and employees and were covered by the government.

degree of acceptability of the risks facing nuclear power plants. The conclusion that emerges from experience with terrorist coverage since September 11 suggests that this risk is not well handled by the insurance market. This was recognized by the passage of TRIA, the Terrorist Risk Insurance Act, which established a role for the Federal Government similar to that assigned to it in the P-A Act.

To more fully understand the losses from September 11 from an insurability perspective, one can compare this event with other types of extreme events that have affected the (re)insurance industry. Table 9.1 presents the twenty largest worldwide insurance losses due to natural catastrophes and man-made disasters from 1970 to 2008. Prior to September 11 losses, the largest loss experienced by the insurance industry was Hurricane Andrew, which devastated the coasts of Florida in August 1992 and inflicted $24.6 billion in claims payments (indexed to 2008) (Swiss Re 2009). When one adds the 6 to 7 billion dollars in payments by the US Federal Victim Compensation Fund to victims of September 11 and their families, the claims from the terrorist attacks are almost twice those from Hurricane Andrew (Congressional Budget Office 2005). Claims from a major nuclear accident could be very much larger even than those associated with September 11.

Table 9.1 **The twenty most costly insured catastrophes in the world, 1970-2008**

US $ billion	Event	Victims (dead or missing)	Year	Area of primary damage
48.1	Hurricane Katrina	1,836	2005	US, Gulf of Mexico
36.8	9/11 attacks	3,025	2001	US
24.6	Hurricane Andrew	43	1992	US, Bahamas
20.3	Northridge earthquake	61	1994	US
16.0	Hurricane Ike	348	2008	US, Caribbean
14.6	Hurricane Ivan	124	2004	US, Caribbean
13.8	Hurricane Wilma	35	2005	US, Gulf of Mexico
11.1	Hurricane Rita	34	2005	US, Gulf of Mexico
9.1	Hurricane Charley	24	2004	US, Caribbean
8.9	Typhoon Mireille	51	1991	Japan
7.9	Hurricane Hugo	71	1989	Puerto Rico, US
7.7	Winterstorm Daria	95	1990	France, UK
7.5	Winterstorm Lothar	110	1999	France, Switzerland
6.3	Winterstorm Kyrill	54	2007	Germany, UK, NL, France
5.9	Storms and floods	22	1987	France, UK
5.8	Hurricane Frances	38	2004	US, Bahamas
5.2	Winterstorm Vivian	64	1990	Western/Central Europe
5.2	Typhoon Bart	26	1999	Japan
5.0	Hurricane Gustav	153	2008	US, Caribbean
4.7	Hurricane Georges	600	1998	US, Caribbean

Sources: Wharton Risk Center with data from Swiss Re and Insurance Information Institute.

Note: This table excludes payments for flood by the National Flood Insurance Program in the United States. In billions, indexed to 2008.

9.8.2 Linking Insurance with Third-Party Inspections Via Public-Private Partnerships[15]

The Price-Anderson Act needs to be modified to provide a more effective way of monitoring utilities and rewarding those that have undertaken risk-reducing measures. Today there is inadequate inspection of nuclear plants due to limited personnel at the NRC and the lack of incentives by utilities to undertake these measures on their own. Low inspection levels (and low usage of other effective methods for compliance evaluation) may lead to low compliance rates and reduce opportunities for government to find and require firms to correct the sorts of risky practices regulations seek to reduce.

Role of Third-Party Inspections

One way to change the situation is to provide economic incentives to utilities to have their plants inspected. After demonstrating that they are operating safely, they could be rewarded with a lower insurance premium. The combination of private inspection and insurance is a potentially powerful one for meeting and often exceeding environmental and safety regulations. If an inspection reveals ways that a company can reduce its safety and environmental risks, and the costs of undertaking this activity can be recouped in the form of lower insurance premiums that justify the expenditure, then firms will want to adopt these measures.

Insurers have an economic incentive to conduct inspections that focus on risk reduction because they want to reduce the likelihood of paying a claim and the size of their payments. The insurer's economic survival depends on estimating the risk of future losses accurately, not on assuring compliance with government laws. To the extent that regulations are well-aligned with risk-reducing behaviors, insurers are likely to uncover noncompliance problems and encourage their correction.

How Inspections Aid Insurers. Insurance is likely to have greater risk-reducing potential if insurers include inspections, along with other forms of risk assessment, as part of the insurance-rating package. Private insurance inspections can play an important role for several reasons. At the most basic level, insured firms will be more aware of environmental and safety risks as well as regulatory obligations. This promises to be especially valuable in areas of health, safety, and the environment that are plagued by low inspection levels.

Gathering Risk Information. Inspections also enable the insurer to determine how firms investing in risk-reducing measures are likely to reduce their

15. This subsection is based on Kunreuther, Metzenbaum, and Schmeidler (2006).

losses. Insurers can also provide guidance to the firm as to what types of actions would be most profitable for them to undertake to meet or exceed compliance with regulations. If insurers increase their inspections of a firm's safety practices prior to policy renewals, firms will have incentives to comply with the regulations.

Use of Claims Data to Modify Existing Standards. Studying information about claims, incidents, and noncompliance may identify recurring events and high-cost problems calling for new laws or standards. If an insurer has a large enough set of clients and can pool information so as not to reveal identities of firms, then it can provide valuable information to the public sector on the types of claims that have been made. This will enable the public sector agency to modify codes and standards in an appropriate fashion.

Rewarding Firms for Reducing Risks. Insurers providing coverage to commercial enterprises always have the option of raising rates to reflect additional risks that they uncover. Insurers can also bestow rewards on firms that operate at the highest level of compliance and take risk-reducing actions beyond their formal obligations. Seals of approval are valuable to the firm to the extent that customers, employees, and investors make decisions on the basis of safety and environmental records of different organizations. Some commercial partners will see the seal of approval as the designation of a quality operation and favor doing business with these firms.

The firm that earns the seal will have an incentive to reveal its third-party commendation to the public as well as to the government. Regulatory agencies can utilize this information to target inspections to firms that have not had this official recognition; thus, there is a greater chance that those who have not complied with the regulation will be audited by a governmental agency. By raising the probability of a public inspection, more and more firms should adhere to regulations over time.

An insurance commendation is likely to have greater veracity than other sorts of third-party certifications because most third-party inspectors are paid a fee for their services by the inspected firm, and therefore feel a constant tug to keep their customer happy without a strong counterbalancing financial tug to identify risks that may require costly corrections. Insurers, in contrast, have a direct financial interest in reducing risk through their inspections.

9.9 Summary and Conclusions

On the general issue of environmental liabilities, it seems clear that the degradation of natural capital in systems as diverse as the climate system or the coastal barrier island systems can lead to significant social costs that are generally not well-covered by current insurance products. These end up as liabilities of the Federal Government by default, often as a part of the portfolio of the Federal Emergency Management Agency.

In the field of nuclear risks, the Price-Anderson Act transfers significant liabilities to the Federal Government. If there is an expansion of the use of nuclear power in the next decade, as appears to be the case, then these liabilities could increase further. Although it is clear that the contingent federal liabilities associated with P-A are large, it is hard to be precise about them. The probability of a major accident at a nuclear reactor (e.g., a core meltdown) and its costs are ambiguous.

There are, however, certain things that are clear. One is that the risk is to some degree under the control of the Federal Government, via the Nuclear Regulatory Commission, if it enforces safety standards and influences the siting of nuclear reactors in remote areas. There is empirical evidence that the NRC does not aggressively pursue and penalize mismanagement of nuclear power stations, and that the Federal authorities are not sensitive to the increase in potential costs associated with siting near densely populated areas. There is scope for better management of this aspect of Federal financial risks, possibly by the use of third-party safety auditors to supplement the NRC. In addition, the premiums charged to utilities under the P-A Act do not reflect their stations' safety risks: this would be another way of reducing the risk of a disaster. Currently there are few incentives for a utility to improve its safety record.

There do seem to be compelling reasons for thinking that Federal intervention is necessary if the risk of nuclear disaster is to be adequately insured. There are many characteristics of this risk that probably make it uninsurable. But that does not mean that the P-A Act is the best solution. We have reviewed the ways in which catastrophic risks are managed in other areas, such as flood, hurricane, earthquake, and terrorist risks. There has been considerably more constructive public debate about these risks than about nuclear risks. Typical of most of these areas is a first insurance layer covered by private insurance markets, with government coverage of losses in excess of the private risk cap. In the case of the P-A Act, the private coverage is just \$300 million per incident, with a pool insurance vehicle covering the next \$10 billion. There is no explicit statement of the government's role and liabilities. The figure of \$300 million surely does not exhaust the private sector's available capital for covering losses from a nuclear power plant accident. For other areas the private sector provides coverage as high as \$10 billion or more. More of the nuclear risk could surely be met through the private sector. This would not only reduce the Federal liability but also provide increased incentives for risk management, sadly lacking under the current regime.

On a more general note, the increased concern with the impacts of climate change on the environment suggests that one rethink the role that FEMA and other public sector agencies at the local, state, and federal levels can play in reducing losses from future disasters. There is a need for innovative private-public sector initiatives to avoid the problems inherent in myopic thinking. For example, in order to encourage residents and businesses to adopt risk-reducing measures with respect to natural and man-made hazards, multiyear contracts such as five-to-ten-year insurance policies and long-term loans should be considered (Kunreuther and Michel-Kerjan 2010). The need for such long-term thinking appears more important today than it did a few years ago, with respect to reducing the catastrophic losses from environmental risks and encouraging a rethinking of the sources of energy that addresses the problems of climate change.

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Comment William Pizer

Key decisions in public policy often come down to efforts to weigh the costs and benefits of various alternatives. In order for such efforts to be meaningful, it is important to include all major sources of costs and benefits—otherwise, what may *appear* to be a reasonable choice can turn out to be quite the opposite when a full accounting occurs. The question would then seem to be, what are the key categories of costs and benefits?

This could be the primary focus of Heal and Kunreuther, who turn their attention to a broad category of such costs and benefits—environmental assets and liabilities—in order to see if there are any lessons for current policymakers. Their chapter breaks down into two parts: first, a review of environmental assets and accounting; and second, a review of environmental liabilities and insurance, with a particular emphasis on nuclear power. Each part offers lessons for improving public policy decisions.

The first section reviews a number of examples where environmental assets have or have not been valued. The Catskills provide significant value to New York City in terms of their ability to cleanse and stabilize the flow of water to New York. Forests offer value in terms of sequestered carbon dioxide that otherwise contributes to global climate change. Oil, gas, coal, and other mineral deposits have very clear market value. Soil provides agricultural productivity. And the climate system, to date, has provided relatively stable climate and weather patterns that have allowed regions to develop and

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