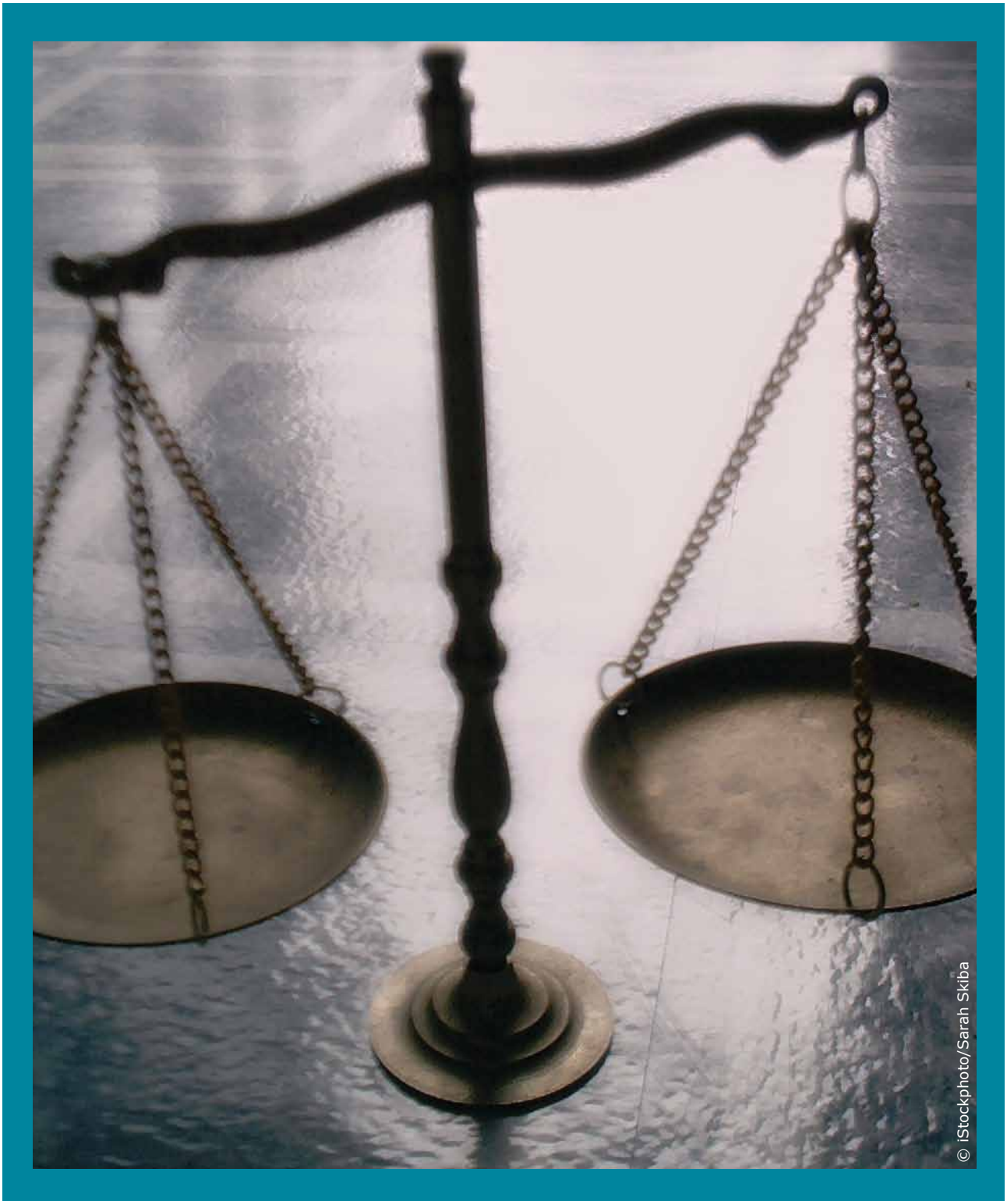
Part D Costs, justice and innovation



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23 Understanding and accounting for the costs of inaction

Mikael Skou Andersen and David Owain Clubb

In political decision-making processes, the burden of proof is often distributed such that policymakers only respond to early warning signals from environmental hazards once the costs of inaction have been estimated.

This chapter revisits some key environmental issues for which estimates of costs of inaction have been carefully developed over many years of research. The aim is to consider the methodological challenges involved in producing estimates that are credible and appropriate rather than present specific estimates for these costs.

The case studies also provide insights into how early warning signals might provide a basis for estimating the costs of inaction, when the science base is less consolidated. For example, the case of nitrates in drinking water illustrates that a precautionary approach to the costs of inaction is quite conceivable. The phase-out of ozone-depleting substances, where early-warning scientists successfully alerted the world to the damaging effects of chlorofluorocarbons (CFCs), provides another important case because additional impacts for global warming actually cause the costs of inaction to be considerably higher than initially believed. This is a reminder that figures for the costs of inaction have often been grossly underestimated.

Finally, in the case of air pollution, making use of different estimates for mortality risk avoidance will help decision-makers to see that there are higher- and lower-bound estimates for the costs of inaction. Even if the lower-bound estimates are perhaps too conservative, with a bias towards health effects, they will in many situations encourage more rather than less abatement effort. Reducing emission loads will also tend to bring relief for the intangible assets of biodiversity and nature.

Making the best use of environmental science and modelling helps to make environmental protection and precaution a priority. Producing cost estimates should not be left to economists alone, but should rather be seen as a starting point for a broader discussion, featuring also the relevant expertise in health, ecology, demography, modelling and science. Well researched estimates, based on interdisciplinary collaboration, can strengthen some of those scattered and diffuse interests, which during the ordinary processes of policy-making have difficulty making their voices heard.

23.1 Introduction

The first volume of *Late lessons from early warnings* reminded us that:

'The costs of preventive actions are usually tangible, clearly allocated and often short term, whereas the costs of failing to act are less tangible, less clearly distributed and usually longer term, posing particular problems of governance. Weighing up the overall pros and cons of action, or inaction, is therefore very difficult, involving ethical as well as economic considerations, as the case studies illustrate' (EEA, 2001:3-4).

In the decade since its publication, there has been considerable interest in addressing and understanding the possible costs of inaction. The Stern review on 'The Economics of Climate Change' for the UK government is a prominent example of how an economist specialising in risk assessment was able to provide credible estimates of the global costs of failure to prevent climate change (Stern, 2007). Stern warned that the likely consequences of continued, unabated global warming would be in the magnitude of 5 % of global GDP annually. He estimated that the costs could rise as high as 20 % when including non-market costs for health and environment and if we factor in the effects on developing countries in an equitable way. In contrast, according to Stern's review, the average expected costs of mitigation for stabilising greenhouse gas concentrations are likely to be about 1 % of GDP annually, while unlikely to exceed 3.5 % of GDP annually.

The Stern review has been subject to much attention and scrutiny, mainly over the so-called 'discount rate' (a measure of how to value costs and benefits in the future — see section below) it used. However, its basic finding that the costs of preventive action were less than the harm caused by inaction was broadly accepted. The Review influenced the political debate, and the UK government subsequently passed the Climate Change Act, which called for an 80 % reduction in greenhouse gases by 2050. The Stern review also influenced the European Council in its decision in March 2007 to embark on a more active climate policy.

The subject of the 'costs of inaction' has subsequently become a recurrent topic in deliberations over climate policy, and more recently, with respect to biodiversity. The OECD (2008) has provided an overview of studies addressing the costs of inaction for a range of other environmental issues, including air pollution, water pollution, natural resource depletion and industrial accidents. To understand the costs of inaction, one must express in monetary terms the damage that will be caused if no or limited intervention is agreed. Stern did this by taking a risk-analysis approach, which unlike the more static cost-benefit approach, emphasised a range of outcomes and the uncertainties involved in the calculations.

It is essential to understand that under an economics perspective the 'costs of inaction' are simply analogous to the benefits that can be obtained with proper controls (OECD, 2008:49). Addressing the 'costs of inaction' involves the same methods used to account for benefits in conventional cost-benefit analysis. They have in recent years been underpinned by the availability of computing and modelling capacities, that better allow environmental scientists and environmental economists to account for the complexities and uncertainties at stake, and hence to integrate a precautionary perspective.

This chapter reviews some of the methodologies used to produce estimates for the costs of inaction. Not all the case studies here will match chapters in *Late lessons from early warnings* Volumes 1 and 2. Instead, the case studies provide a generic perspective, which will be of some relevance to historical, current and future case studies.

The first case study we look at is the phasing out of lead in petrol. We use this example as a starting point for a discussion of the subtle differences between scientific proof and scientific evidence. In our second case study, we turn to the issue of nitrates in drinking water in order to show that costs of inaction can be estimated even when there are uncertainties over the long term effects of inaction. In the third case study, we explain some of the methodological controversies that have raged over how to account for the costs of inaction related to mortality risks, which is relevant for air pollution for example. By way of illustration we present in separate boxes monetary estimates of the environmental burdens related to lead and mercury, SO_2 with other air pollutants as well as to ozone-depleting substances (ODS).

23.2 Should we require proof or evidence to account for the costs of inaction: insights from lead phase-out

Heinzerling, Ackerman and Massey (2005) provide a concise overview of the role of scientific and economic analysis in eventually ending the use of

lead in gasoline in the United States. It was research by Herbert Needleman (see Chapter 3 on lead in petrol) on the relationship between lead levels in children's blood and cognitive impairment that made it possible to state in quantitative terms the loss of IQ involved. Heinzerling et al. describe how economic analysis eventually came to the rescue of the lead phase-out by translating this IQ loss into monetary figures. Lower IQ could be shown to result in lower life-time income, which could in turn be translated into an implied cost of inaction (see also Nichols, 1997).

This approach differed from the simple 'willingness-to-pay' studies that previously had been referred to by economists. In these willingness-to-pay studies, parents were asked how much they would spend to prevent exposure of their children. These studies were problematic in that they expected firm monetary preferences to emerge for a problem the dimensions of which few parents would understand. The shift in focus away from willingness-to-pay studies meant that the findings of the lead scientists were used directly in economic assessments of the costs of inaction. The human bones absorb lead, and Needleman's breakthrough was to measure the stocks of accumulated lead in the first 'baby' teeth of children, rather than the level of more recent lead exposure in their blood. One challenge was to establish to what extent blood lead levels reflected ambient concentrations of lead in air. The lead case is described in more detail in Box 23.1.

Today there are numerous hazards and challenges for which we have only limited scientific evidence, and for which it will take many years to accumulate the same understanding as was reached in the case of lead. Economists trying to estimate the costs of inaction will often ask whether there is 'scientific proof', but it must be acknowledged that there is usually not a simple answer to this question. Economic analysis should therefore consider the less certain levels of knowledge that make up scientific evidence in order to explore the magnitude and risks of potential impacts suggested through early warning signals.

We sometimes tend to think of knowledge and lack of knowledge in a simplistic way, believing that research is a process that can transform lack of knowledge into indisputable proof. More realistically, our knowledge base is less clear-cut. It often has a focused nucleus of complete understanding, with a surrounding area where many linkages and relationships are not understood with the same rigour and underpinning. Early warning signals are often located in this blurred area where linkages are not fully understood.

The Treaty on the Functioning of the European Union (TFEU), which establishes the precautionary principle as one of the guiding principles of environmental policy, does not generally mandate a requirement for scientific *proof*. For instance, TFEU art. 114 no. 5 — the so-called environmental guarantee — allows a Member State to introduce unilaterally more stringent measures in areas where there is 'scientific *evidence*'. The precautionary perspective (TFEU art. 191) is really about acting *in the absence* of scientific proof (see Chapter 2 on the precautionary principle).

Although Needleman's research was able to document a relationship between low doses of lead and IQ impacts on children, not all aspects of lead exposure were fully understood. Today we can take advantage of computerised environmental models to account for blood lead concentrations as a result of the lead accumulation over time in the various compartments of the human body. In this way, we can clarify the link between low-dose exposure and the resulting, age-dependent blood lead in children (Pizzol et al., 2010). But the use of such tools remains the exception. For example, the chemical PCB is a substance for which the abatement costs are now counted in billions of euros (von Bahr and Janson, 2004) while welfare economic damage costs are largely unknown. Therefore, when it comes to substances for which the knowledge base is less developed, it will be necessary to explore the potential costs of inaction by relying on evidence from early warning signals. These harm costs could for instance be calculated by looking first at the already-proven impacts of high doses in the work environment, and then scaling linearly to low doses.

23.3 Using warning signals to estimate the costs of inaction: risks from nitrate in drinking water

The European Union's 1980 directive on drinking water quality (80/778/EEC) introduced a maximum admissible concentration value (MAC) for nitrate contents in drinking water, based directly on WHO guidelines. Drinking water with MAC levels of nitrates is suspected to increase the occurrence of *methaemoglobinaemia* in vulnerable individuals, particularly babies (leading to the potentially fatal phenomenon of 'blue' babies, cf. NSW, 2006). At MAC-concentration levels, drinking water nitrate will double the amount of nitrates that the average person would ordinarily consume from other sources.

Box 23.1 Costs of inaction on lead and mercury

Why does lead matter?
Lead is a potent and pervasive neurotoxicant that travels widely throughout the body once ingested or inhaled, and affects virtually every organ or system in the body (Meyer et al., 2008). Children and pregnant women have a higher absorption rate of lead due to constant bone remodelling, which arises from skeletal development (Barbosa et al., 2005). The impacts upon children are profound, because not only is lead more easily absorbed, it is also more damaging to the developing nervous system. Even extremely low Bloodstream Lead Levels (BLL) can have significant impacts on future academic achievement (Miranda et al., 2011), a fact that was a material consideration in the 2005 US Centre for Disease Control's recommendation that there is no safe BLL for children (ACCLPP, 2012). These changes in development are irreversible. Exposure to even low levels of lead during pregnancy will cause permanent and irreversible developmental harm, which manifests itself in lower educational achievement in later stages (Lourdes et al., 2006).

The damages arising from lead have been described as nothing less than a 'catastrophe' for public health (Landrigan, 2002). Lead damages almost every biochemical process in the human body (Gidlow, 2004; Needleman, 2004). It damages fertility and neuropsychology, as well as distorting enzymes, structural proteins and mitochondrial cristae. It also pushes out calcium from natural neuron signalling processes (see Box 3.1 on children and lead in Chapter 3).

Recognition of the problem
Lead has been recognised as a health problem since Roman times (Reddy and Braun, 2010). But it was not until 100 years ago that an Australian doctor identified the critical vulnerability of children to lead (Taylor et al., 2010). But despite multiple early warnings, lead continued to be used as an additive in paint for many years in Europe, America and Australia.

The most harm was caused by the use of lead as an additive to motor vehicle fuel, which resulted in widespread environmental exposure and serious health impacts for hundreds of millions of people. Lead was first added to motor fuel in the 1920s, and it took many decades before developed nations began to phase out the practice.

The history of the use of lead as an additive in petrol is a sad testament to the desire of companies to make profits regardless of the consequence to human health. Other, much less harmful alternatives to lead were available to the petrochemical industry, but they were not adopted because they were not patent-protected, and would therefore have greatly reduced profits for the sector (Ackerman et al, 2005). The global harm caused by leaded gasoline is undoubtedly high, not least because extremely high BLL have been measured in different cities. For example, the average BLL of the sampled population in Bangkok in the 1980s and 1990s was 40ug/dl, levels at which effects such as headaches, slowing of motor nerve conduction and anaemia may occur. Death may occur at BLL of about 100ug/dl (Olson, 2004).

In 1981, the EU introduced a limit of 0.4 gram of lead per litre of leaded gasoline. Use of lead became less attractive following the requirements for installation of catalytic converters in cars. Germany introduced different tax levels for leaded and unleaded petrol in 1985, an approach copied in several other Member States (Hammar and Löfgren, 2004). This meant that by the time the European Union prohibited use of leaded gasoline in 2000, there was little protest from any quarter. As of January 2011, only six countries continue to allow leaded gasoline: Iraq, Yemen, Algeria, North Korea, Burma and Afghanistan.

Economic impacts
In the US, economic analysis was instrumental in convincing the Reagan administration of the desirability to phase out lead in petrol (US EPA, 1985). These analyses explored the loss of IQ in children exposed to lead, a phenomenon that had been demonstrated by scientists. Cognitive impairment of children could be shown to result in reduced expectations for life-time income (Salkever, 1995). Statistically, a loss of one IQ-point can be shown to cause a loss in life-time income of 2-3 % (highest for females). There is no lower threshold for the lead-induced cognitive impairment of young children, so all emissions impair cognitive function (Schwartz, 1994).

Because the harm from lead relates to a future stream of income over a lifetime, the discount rate used to convert future earnings into a net present value decisively influences the final monetary estimate for the

Box 23.1 Costs of inaction on lead and mercury (cont.)

harm caused. In studying the harm cause by lead, US economists used a discount rate of 10 %, while an EU study abstained from any discounting ([1]). Early childhood IQ-losses, such as those that arise from undernourishment or poisoning, can be significant. IQ levels have been demonstrated to influence dramatically the relative affluence of nations, and are therefore a social good (see Figure 23.1).

When using a *social* discount rate of 1.4 % (cf. Stern, 2007; European Commission, 2008) the result is a damage estimate of EUR 1.50 per gram of lead emitted in urban areas (Andersen, 2010). The discount rate is not the only factor that influences the cost estimate. Estimates of the cost of damage can also be greatly influenced by assumptions about how lead enters the food chain ([2]) and by assumptions about so-called 'resuspension'. Resuspension is the process by which lead emitted years ago is deposited on the soil, but then blown up into the air again by the wind.

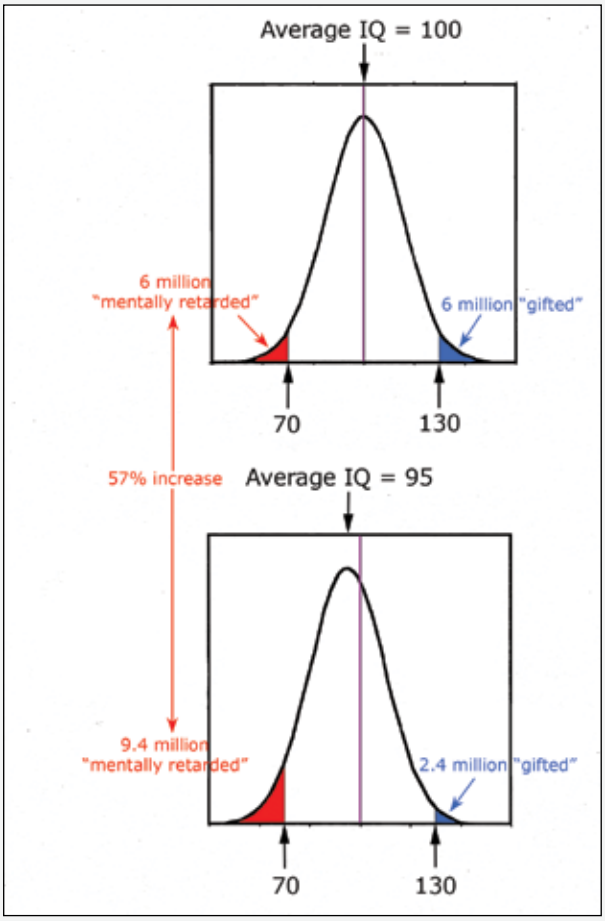
Considering that until the 1970's, gasoline contained about 1 gram of lead per litre, valuing lead-associated IQ damages at EUR 1.50 per gram (EUR 1.50 per litre) implies significant annual costs of about 4–6 % of GDP in EU Member States.

Today, lead emissions in the European Union have decreased greatly, and the magnitude of damages from new emissions, mainly from waste incineration and industry, amounts to less than 0.1 % of GDP. Still, further reduction of lead in products (e.g. paints, toys) remains desirable to prevent continued harm to children.

All the lead emitted during the 20th century is dispersed across the environment, contributing each year to renewed harm as some of the lead finds its way back into our atmosphere. Many urban areas have chronically high levels of lead in top-soils. This is sufficient reason to recommend the resurfacing of playgrounds and areas of high activity for young children, as the intake of even a few micrograms may suffice to induce IQ-damage.

Economic damage estimates are based on scientific research on the impact of human exposure to a particular substance. But not all risks are factored into cost-benefit analysis. For example, the ability of lead to trigger cardiovascular diseases in adults (hypertension, nonfatal heart attacks and premature deaths, cf. Menke et al. 2006) has not been included in the above-mentioned damage estimate. Thus, some damage estimates are lower-bound conservative values (Gould, 2009). This tendency for cost-benefit analysis to lean toward conservative values further strengthens the case for adopting a precautionary perspective.

Figure 23.1 Diminished IQ stunts economic development



Note: This graph shows the social impact of a drop in average population IQ. For example a 5-point drop could raise by 57 % the number of individuals considered neurologically impaired, with implications for social and economic development. It also significantly lowers the number of intellectually gifted children.

Source: www.ourstolenfuture.org.

([1]) The US EPA study due to its use of a private discount rate implied a damage cost of 8 US cents$_{1983}$ per gram lead, while the European study with no discounting implied a damage cost of 5.9 EUR$_{2004}$ per gram lead.
([2]) Spadaro and Rabl (2004) indicate a ratio of 1:25 between inhalation and ingestion (intake) from food.

Box 23.1 Costs of inaction on lead and mercury (cont.)

Why does Mercury matter?
Mercury has a long atmospheric lifetime (6–18 months), which means that once it is released from a source anywhere in the world, it can be transported globally, hence its characterisation as a 'global pollutant'. After deposition in ground or water, mercury can be transformed. The process by which this happens is primarily microbial action, which turns mercury into methylmercury. Methylmercury can 'accumulate' as it progresses up the food chain. For example, an animal could eat a smaller animal that has eaten mercury, exposing the larger animal to all the mercury consumed by the smaller animal in its lifetime. This results in ever higher levels of mercury being found in larger predator animals. Human health can be adversely affected by this process of accumulation if organisms with high concentrations of mercury are ingested. This is a particular problem in consumption of predatory fish, notably tuna and shark (Shimshack and Ward, 2010). Pregnant women are at particular risk, as mercury readily passes through the placenta, concentrates in umbilical tissues and leaches into breast milk. Methylmercury is a developmental neurotoxicant , and high environmental exposure to this compound is associated with a statistically significant reduction in IQ in developing children.

Recognition of the problem
Despite the official acknowledgement of Minamata Disease (a sickness affecting people exposed to methylmercury in the Japanese city of Minamata, see Chapter 5) in the spring of 1956, success in tracing the cause to the mercury discharges from an industrial facility took several years. It was not until 1968 that the Japanese Government 'announced its opinion', that factory effluent was directly responsible. An official apology was finally made at the 50th anniversary of the discovery of the disease (Japan Times, 2006) ([3]). Although large-scale acute cases of mercury poisoning are relatively rare, the more general result of lower IQ due to the developmental neurotoxicant effects of methylmercury continues.

Economic impacts
Mercury damages the developing brain and reduces IQ, just like lead (see above). And like lead, it is a substance that has only harmful effects. This is in contrast to other metals that are also toxic at high doses, but of which the human body needs a certain minimum to survive. Several studies have attempted to calculate the costs for diffuse poisoning (i.e. poisoning from many different sources) by mercury. Despite the wide uncertainty in these figures, they demonstrate that the impact is far from trivial.

Axelrad et al. (2007) created a 'dose-response' model to assess the effect on IQ of each additional 'dose' of mercury exposure by performing an integrative analysis of studies from New Zealand, the Seychelles and the Faroe islands. Their central estimate is that for every 'part per million' increase in mercury in the hair of an expectant mother, the child suffered a 0.18 point decline in their IQ ([4]). Concentrations of mercury in hair can be converted into blood concentrations, or concentrations in the umbilical cord, using established factors. As is the case with other mercury studies, the authors assume that there is a minimum threshold (0.1 ug per day per kilogram bodyweight) below which no effects of mercury occur.

For low doses, the time window during which the brain is affected by mercury needs to be considered. The sensitivity of the brain to mercury is greatest during the early development of the body. The epidemiological studies all assume that once a person is exposed to mercury, the effects on their IQ are both measurable and irreversible, remaining with the person throughout their lives. Since the dose-response function refers to maternal hair concentration and effect on children's IQ, it implicitly includes the effect of mothers' diet during pregnancy and early infancy of her child while she is nursing.

Spadaro and Rabl (2008) have calculated the marginal impact of low-dose mercury emissions. Applying an estimate for the monetary value of a 'global' IQ-point (i.e. the value that an extra IQ point brings a person in terms of lifetime income), Spadaro and Rabl report a marginal damage cost per kilogram of mercury emitted of about USD 1 500. If not assuming any threshold to the impact of low doses, the cost is reported to be USD 3 400 per kg. These estimates are conservative compared with the average damage cost of over USD 6 000 USD per kg implied by one US EPA study (where a 33 tonne change in mercury emissions would cost USD 210 million), which used a different methodology and did not have any threshold for pre-natal exposures (Griffiths et al., 2007).

A study in Greenland, where three quarters of newborns have elevated blood concentrations of mercury, even though there are hardly any local emissions, estimated a damage of 59 million dollars per year (Hylander and Goodwin, 2006). This translates to about USD 59 000 for each new born child. The traditional diet in the Arctic region of fish and sea mammals serves as a sink for global mercury emissions by means of the accumulation process described above. Global mercury emissions are projected to increase by 20 % by 2020 (relative to 2005 cf. AMAP, 2011:143).

([3]) 'Koizumi issues official Minamata apology', The Japan Times Online, 29 April, 2006, http://search.japantimes.co.jp/cgi-bin/nn20060429a4.html.
([4]) A part per million is roughly equivalent to the concentration of a single drop of a substance in 50 litres of water.

In addition to a MAC-value of 50 mg NO_3 per litre, the directive introduced a complementary 'guide value' of 25 mg NO_3 per litre. When revising the directive in 1998, the precautionary guide value for nitrate in potable water was deleted and only the MAC-value retained. The main reason for abandoning a guide value was the absence of scientific proof to underpin it.

Starting with the introduction of the drinking water directive (80/778/EEC), the European Union introduced several initiatives to reduce environmental pressures from nitrogen. One such initiative is the nitrogen application ceiling for agricultural land, and the associated regulations on animal manure that were introduced with the Nitrate Directive (91/676/EEC). The Urban Waste Water Directive (91/271/EEC) also introduced constraints for emissions of nitrogen from sewage and industrial effluents. The protection of drinking water was not the only goal in these efforts to reduce nitrate leaching and emissions. Policy makers were also motivated by concerns over eutrophication in shallow and open coastal waters. Over the years, many conflicts have appeared over the costs associated with both these directives. Farming interests in particular have requested derogations and exemptions from regulatory requirements aiming to reduce nitrate loads.

No analysis has so far been carried out in Europe to explore how the possible benefits of these nitrate regulations compare to the costs of implementing them. The evidence that nitrates have adverse health effects is contested. In particular, there has been controversy over the extent to which gastric cancer is related to nitrate intake. The World Health Organization experts maintain that 'a link between cancer risk and endogenous nitrosation as a result of high intake of nitrate and/or nitrite and nitrosatable compounds is possible' (WHO, 2007:12). WHO normally requires at least three different studies establishing comparable evidence before accepting a link to exposure as conclusive, but in the case of nitrate there are few well-designed epidemiological studies in the international scientific literature.

Chronic impacts resulting from exposure over longer periods of time due to elevated levels of nitrate in drinking water have caused particular concern. In order to detect such influences, epidemiological cohort studies, which monitor health effects in a large population sample over a series of years, are required. Such cohort studies are both laborious and costly, and they often face difficulties with establishing the specific historical exposures. At present, the international scientific literature reports results only from two cohort studies regarding nitrate, and their results are ambiguous.

One study by Weyer et al. (2001) reports an increased incidence of bladder cancers in a population cohort of 10 000 women aged 55 or more from Iowa, US — a state with intensive agricultural practices, and high levels of nitrate in public utility water supply. A more recent study could not detect an increased incidence of bladder cancers in a population cohort in the Netherlands, presumably because nitrate levels in Dutch public water supply are rather low.

The Iowa study was published after the EU Council of Ministers abandoned the 25 mg NO_3 per litre guide value for nitrate in drinking water. Along with other types of studies, the Iowa study suggests that health effects can be detected well below the MAC-value and with lower thresholds of 15–25 mg NO_3 per litre. Hence there appear to be costs of inaction at stake, but a relevant question is: how significant are they?

The studies provide evidence from which nitrate health effects can be quantified. A quantification of these health effects is useful for estimating the *potential* costs of inaction — the risks in other words. For instance, the World Bank (2007) has used those studies that show a connection between ill health and nitrate exposure as a basis for providing rough estimates of the health benefits associated with reducing nitrate exposures. More detailed studies have taken a similar point of departure. Van Grinsven et al. (2010) explore the health risk costs related to colon cancer from nitrates, and arrive at a level of EUR 0.7 per kg of fertiliser nitrogen. Andersen et al. (2011), in the EU FP7 EXIOPOL project, explored different river catchment areas and arrived at site-specific estimates based mainly on figures for bladder cancers derived from Weyer et al. (2001). Their mean estimate is EUR 0.3 per kgN-loss, but they report higher health risk costs for specific Member States, for example the United Kingdom and Belgium at a level of EUR 1.3 per kgN. In some urban areas, the health risk costs are much higher. Consequently, it can be estimated that the risk costs of inaction on nitrate in drinking water amount to EUR 2.6 billion annually for the United Kingdom alone. This figure is comparable to a previous estimate for all external costs of UK agriculture combined (Pretty et al., 2001).

Since there are also other costs related to nitrogen, arising from the pollution of surface waters, ammonia evaporation, and greenhouse gas emissions of N_2O, these figures taken together

would suggest that a precautionary approach is warranted. The abandoned guide value for nitrate in drinking water also deserves reconsideration.

23.4 Air pollution: how to account for the mortality risks from inaction?

The willingness of individuals to make economic sacrifices in order to reduce potential statistical mortality risk is determined by their risk aversion. People make decisions to this effect with many everyday choices, such as adding airbags and other safety devices to their car. In the United States, the authorities have determined risk aversion by resorting to wage-risk analysis. This involves exploring what wage premiums individuals require for more risk-prone occupations, and on that basis have estimated the value of preventing a fatality at about 5.5 million USD_{1999} (1999 prices).

In Europe, there has been more emphasis on applying specific values comparable to figures used in transport economics for avoiding fatalities. Still, air pollution has a risk profile different from road traffic: The average road victim is middle-aged, while victims of air pollution are believed to be mainly people over 65 (Pope, 2002). While a road victim on average loses 30–40 years of life expectancy, the average air-pollution victim may stand to lose only a few years. The European Commission, on the basis of expert advice, has opted to value a statistical life (VSL) at 1.4 million EUR_{2000}, but has adjusted it downwards to about EUR 1 million for air pollution to account for the advanced age of the typical air pollution victim. Similar adjustments proposed in the United States were however met with public outcry and were branded as a 'senior death discount' (NYT, 2011).

In the economics literature, VSL remains the conventional metric for the valuation of statistical fatalities. In recent years, it has been challenged by the adoption of more conservative estimates, based on the specific number of life-years lost. There has therefore been a debate over whether it would be reasonable to exchange VSL-figures with VOLY: the value of a life-year (Hofstetter and Hammitt, 2002). Questions that have been addressed include whether life-years towards the end of an individual's life should be valued more highly than an average life-year (as more precious) or rather should be valued lower, as reduced health and vigour is likely to reduce life-quality. VOLY-values can be derived schematically from VSL, by assuming that the average VSL represents a loss of life expectancy of 3–40 years as in road traffic.

OECD (2006) guidelines for environmental cost-benefit analysis recommend the use of VSL for acute mortality (as in road transport) and to introduce VOLY for cases of so-called 'chronic' mortality, (the result of elevated exposures to harmful substances over longer periods of time), such as air pollution or nitrate in drinking water (See Box 23.2 on SO_2 and other air pollutants for results obtained with the OECD approach).

In contrast, the Science Advisory Board of the US EPA maintains that the only solid value available for quantifying risk aversion in monetary terms is the VSL (US EPA, 2010:12). The obvious implication of the US approach is that it accords a higher monetary value to environmental risk reduction than Europe. Unfortunately, US economists are facing decreased political acceptance of the recommended approach. This was reflected in the recent decision by the Obama administration — acting under political pressures — to withdraw proposed restrictions on ozone pollution, despite the high costs of inaction.

VOLY-based figures provide perhaps only a lower-bound estimate for the benefits of action, but in many cases these conservative values are already sufficient to justify abatement action. The European Commission's impact assessment of the thematic strategy on air pollution (CAFÉ; Clean Air For Europe cf. AEA, 2005) programme decided to tackle the ambiguity over VSL and VOLY values simply by reporting different sets of benefit estimates. It then left it to policymakers to make a decision based on these two different pieces of information. While the most conservative estimate suggests that air pollution costs account for roughly 3 % of GDP in EU-25, the highest estimate amounts to 5 % (see Box 23.2 on SO_2 and other air pollutants). The acknowledgement that economics may not offer a mature consensus corroborates the role and significance of the precautionary principle. The Stern review of climate change reflected similar uncertainties, reporting different estimates, rather than presenting one specific economic figure.

23.5 Should we accept a discount on costs of inaction arising in the future?

The costs of inaction will often only be felt in the future. This is certainly the case for the impact of lead on IQ-loss or the health implications of living with high levels of air pollution and drinking water nitrate. In the case of the skin cancers induced by the ozone 'hole', impacts are expected to peak only after

Box 23.2 Costs of inaction on sulphur dioxide (SO_2) and other air pollutants

Why does air pollution matter?
Sulphur dioxide (SO_2) is a colourless, pungent gas that is a by-product of combustion at power plants, and also arises from natural sources such as volcanic eruptions. SO_2 emissions are a particularly important issue because they are produced in the combustion of coal, which is a major component of the electricity generation systems of many major economies (see Figure 23.2).

Sulphur dioxide has many potential environmental impacts, including its conversion to various acidic compounds (sulphuric acid, sulphurous acid) that can damage tree, plant and animal life (see EEA, 2001, Ch. 10 on sulphur dioxide, lungs and lakes). The converted and hence secondary formation of particulates (for example SO_4) after transport and chemical action cause severe health problems too.

Health impacts
Inhaled sulphur dioxide readily reacts with the moisture of mucous membranes to form sulphurous acid (H_2SO_3), which is a severe irritant. People with asthma can experience increased airway resistance with sulphur dioxide concentrations of less than 0.1 ppm when exercising. Healthy adults experience increased airway resistance at 5 ppm, sneeze and cough at 10 ppm, and experience 'bronchospasm' at 20 ppm (ATSDR, 2011).

The further risk posed by SO_2 is in its subsequent conversion to sulphate particles, and as a precursor to PM (particulate matter), contributing to ill-effects caused by PM_{10} (particulates of larger size) and $PM_{2.5}$ (particulates of smaller size). A meta-study of the mortality effects of ambient particulate sulphates demonstrates a strong correlation between mortality and the atmospheric density of the pollutant (i.e. the amount of pollutant present in the air, Smith et al., 2009).

Recognition of the problem
The first deadly impacts of an air pollution episode had been reported as early as 1929 in Wallonia, Belgium. Another significant and widely-recognised case of health impacts from sulphur dioxide was the Great Smog which affected London in 1952, causing an excess mortality of as many as 13 000 deaths (Bell et al., 2003). The smog was caused by a high level of air-borne pollutants, which remained in the city due to unusually still weather conditions. The response to this event was to propose remedies such as increasing the height of chimneys. Whilst this alleviated the problem, it also dispersed the pollution more regionally, and caused the acidification of rain, lakes and rivers in Scandinavia.

Japan also suffered badly from sulphur dioxide pollution in the three decades of industrialisation that started in about 1950. In all, more than 100 000 people were registered by the Japanese ministry of the environment as having suffered health impacts as a result. Sulphur dioxide pollution, known at the time as Yokkaichi Asthma, is listed as one of the four 'big pollution diseases of Japan' (Committee, 1997).

Economic impacts
In the 1970s, some claimed that the problem of sulphur dioxide pollution were not severe enough to warrant expensive action. Some even called it a 'million dollar problem with a billion dollar solution' (Opinion, 1977). The link between atmospheric concentrations of sulphur dioxide and sulphate to increased mortality rates was only gradually accepted. However, when one factors in not only the costs of morbidity (the sickness caused by sulphur dioxide) but also those of mortality (the deaths caused by sulphur dioxide) it is clear that the health costs of inaction on air pollution damages should indeed have been counted in billions too.

Pope et al. (1995, 2002) showed how increased rates of mortality are consistently associated with high ambient levels of pollutants. Most of the deaths were seen to occur in response to chronic exposures over extended time periods, rather than in response to shorter periods of exposure. Their findings were based on a population cohort of more than 500 000 individuals, who had been interviewed about health status, smoking habits and other potentially confounding variables. The American Cancer Society had obtained individual death certificates from deceased participants in the cohort, which allowed control for death caused by air pollution exposure. The US EPA decided to require a complete reanalysis of the data by an independent research team before finally accepting the findings — it led to the same results.

In 2005, the European Commission commissioned a comprehensive cost-benefit analysis when preparing its Thematic Strategy for Air Pollution. It also invited the World Health Organization (WHO) to review the

Box 23.2 Costs of inaction on sulphur dioxide (SO_2) and other air pollutants (cont.)

health effects evidence available. Because of the methodological debate over the appropriate valuation metric for the risks to human lives (see discussion in main text of this chapter), the assessment presented different estimates. The lowest estimate, based on a VOLY metric, came to a total cost of air pollution for the EU-25 of EUR 276 billion, equivalent to 3 % of GDP. The highest estimate, based on a VSL metric, came to a total cost of EUR 427 billion, close to 5 % of GDP (AEA, 2005).

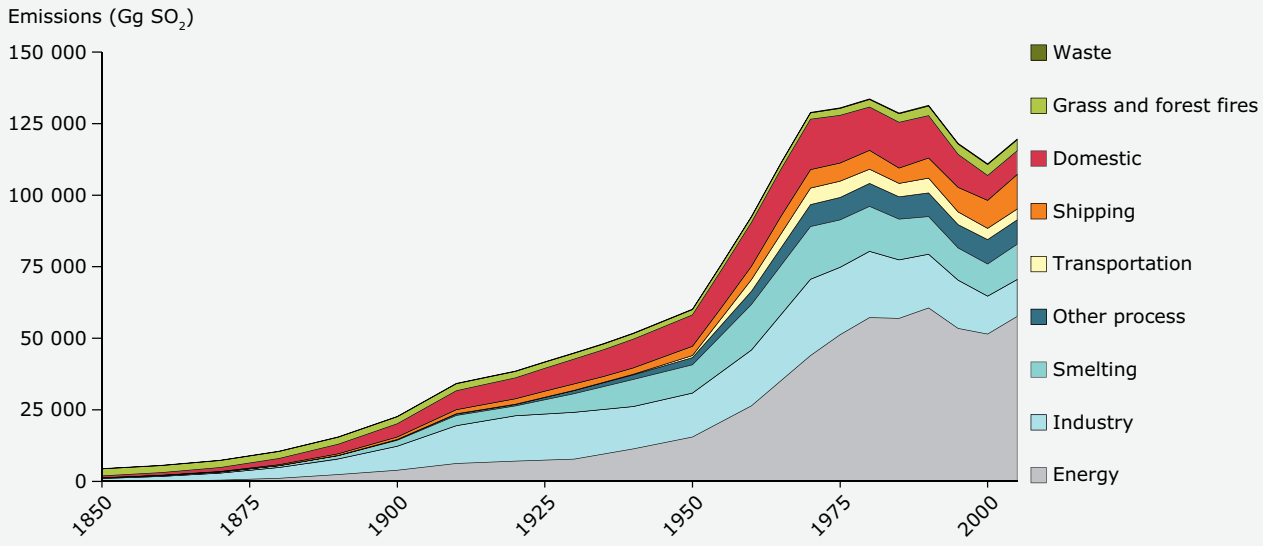
The costs were seen to differ considerably among Member States. In Poland and other new Member States, the air pollution costs (using 2000 as the reference year) varied between approximately 15 % and 22 % of GDP depending on the metric (AEA, 2005). These costs referred to the combined exposure to particles from SO_2, NO_X and primary PM.

Although these figures do not include all relevant costs of inaction — for instance in relation to biodiversity — the figures suffice to justify further action to reduce air pollutants. While the damage cost per kilo of SO_2 ranges from EUR 5 to 9 per kg SO_2, marginal abatement costs start from below EUR 1 per kg SO_2 (Rive, 2010). Theoretically, it would be desirable to pick the lowest-hanging fruit first and focus on the most cost-effective measures, but in reality there are large benefits for nearly all efforts regarding SO_2 abatement.

A cost-benefit assessment becomes highly complex when multiple types of emissions are considered jointly (SO_2, NO_X, VOC, O_3, NH_3 and PM). There are non-linearities at play in the atmospheric transport and chemistry, for instance relating to ozone, which must be taken into account. Some integrated assessment models have been created to study these situations that feature complex mixtures of emissions. They typically produce scenarios for different levels of pollutants (e.g. SO_X, NO_X) and come up with a best-cost solution for meeting various environmental outcomes. The technically feasible reduction of air pollution has been estimated at EUR 56–181 billion equivalent to 0.6–2 % of GDP in EU, which are the costs that could be avoided by introducing appropriate controls (AEA, 2005).

Japanese industry was a pioneer in air pollution abatement. In 1975, investment in air pollution abatement accounted for 18 % of Japanese capital investment and 6.5 % of GDP. The OECD (1977) has reviewed the experience and concludes that 'the impact of relatively high pollution abatement costs on macro-economic magnitudes, such as GNP, employment, prices and foreign trade is practically negligible'. In fact, these investments accelerated technological innovation, raised product quality and lowered technical costs. Even today, Japanese companies control many of the patents and licenses for air pollution control equipment, and benefit from sales globally, demonstrating the economic significance of being a pioneer in environmental technology.

Figure 23.2 Global SO_2 emissions 1850–2005 by end-use sector



Source: Smith et al., 2011.

60 years. These delayed effects present a particular problem for estimating the costs of inaction.

To allow for the comparison of monetary estimates at different points of time, economists typically use 'discounting' techniques, whereby all estimates of future costs are discounted — or reduced in absolute terms — into net present values. There are two textbook reasons why economists assume the future is not worth the same as the present to an investor. Firstly the investor may not be alive when the return on the 'investment' is made, and secondly, the prospect of continued economic growth and technological progress means an investor expects to be richer when the return is made, meaning that the return will have less value in the future. For this reason economists apply a discount rate, reflecting mainly these two aspects, and adjusting them for time preferences and consumption value.

To many non-economists, the implied shrinking of future values with the discounting technique is at odds with the core idea of intergenerational equity that is central to sustainability. A related problem is that many economists are applying discount rates that are typically used in the corporate sector — rising up to as much as 10 % — without reflecting on the specific context of environmental challenges.

As pointed out in the Stern report, time preference discounting is less relevant for a society than to an individual. Firstly, society is not mortal. There is only a small risk that societies would be discontinued, whereas an individual investor faces a much greater risk. For this reason, Stern recommends representing this risk of social 'mortality' with a tiny discount rate of 0.1 %. As for the second aspect of discounting, the consumption discount rate that seeks to compensate for continued economic growth in the future, Stern maintains it should be based on expectations for future economic growth, net of inflation. Only a very small number of countries have expectations for annual economic growth rates of 10 %. In Stern's analysis of climate change policy with the PAGE model, he simulated many different trajectories of economic growth for the future decades and came to an average expectation of 1.3 % per annum. Stern's review argued that even when discounting the stream of future benefits, the aggregate sum of avoided damages — from 5 to 20 % of annual consumption — would well exceed the involved costs. Table 23.1 illustrates how the social cost of carbon depends crucially on the discount rate chosen.

Many environmental projects have much shorter time horizons than climate change policy. For example, investments in sulphur scrubbers for air pollution abatement have only a 10 or 20 year lifetime. With shorter project lifetimes than in climate change policy, there will be less 'shrinking' of the future, even for the lifetime-loss of income of the lead-poisoned child (see estimates in Box 23.1 on lead). For mortality risks, discounting is not very important because the VSL must be adjusted upwards for expected economic growth, which will cancel out the consumption component of the discounting, leaving only the 0.1 %.

Table 23.1 Effect of the discount rate on the estimated costs of inaction

Discount rate (%)	Discounted costs of inaction (% of GDP-equivalents)
1.3	14.7
1.8	10.6
2.3	6.7
2.8	4.2

Source: Stern, cited from OECD, 2008:96.

23.6 Concluding remarks

We have discussed above some of the problems with the willingness to pay model of estimating the costs of inaction. In what has become a classic discussion of this model, Diamond and Hausman (1994) raise two other difficulties with willingness-to-pay and the so-called 'contingent valuation method' (CVM) it uses. Firstly, because stated willingness-to-pay is hypothetical, there is an inherent risk that any respondent will overstate their preferences, neglecting their level of income and therefore their real ability to actually pay. Secondly, there is the tendency of willingness-to-pay results to be inconsistent across different surveys. For example, the willingness-to-pay for cleaning up one lake might be similar to the willingness to pay for cleaning up five. People may simply express a desire to contribute EUR 50 for a good purpose, but have no specific individual preference as to the amount of the public good in question. These are strong methodological critiques to the use of monetary estimates derived from CVM.

Europe has acted cautiously in mandating formal requirements for cost-benefit analysis. At Member State level, there is a fairly limited tradition as part of formal legislative processes. Although the concept has found its way into common-day language across the European continent (Germans for instance speak of 'Kosten-Nutzen analyse'), it is perceived by many as a somewhat American-style approach to policymaking processes. The Dutch felt compelled to rename it as

Box 23.3 Benefits of early action on ozone depleting substances

Why do ODS matter?

The ozone layer absorbs most of the high-frequency ultraviolet radiation that could cause damage to life on Earth. Ozone Depleting Substances (ODS) are chemicals that can survive long enough in the atmosphere to migrate to ozone-rich areas, in the upper atmosphere, some 25 km high. At this altitude, ODS then undergo reactions that break down ozone molecules (see also Figure 23.3). If the emission of ODS is allowed to continue or increase, the ozone layer will reduce in thickness, increasing the quantity of harmful UV radiation that reaches the surface of the Earth (Molina and Rowland, 1974 — see also Chapter 7 on halocarbons and the ozone layer in *Late lessons from early warning* Volume 1 (EEA, 2001)).

Exposure to UV radiation has significant health implications for many forms of life, including humans. Excessive exposure is linked to increasing rates of skin cancer, cataract development and reduced capacity to resist bacterial and viral infection (WHO, 1994). Insufficient exposure can also create problems, notably by leading to vitamin D deficiency, and damaging crop productivity.

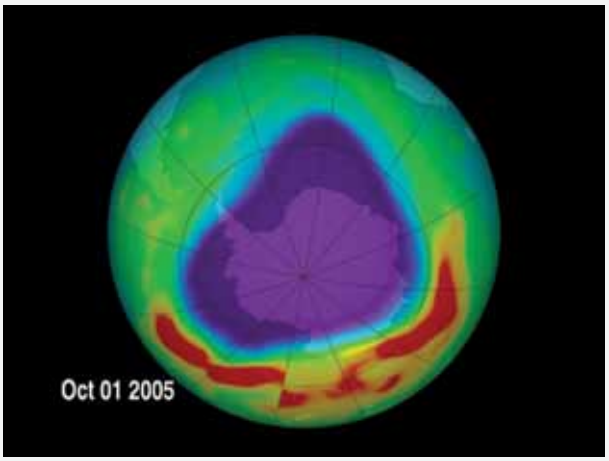
UVB radiation is a major causal factor in the development of melanoma and non-melanoma skin cancer (NMSC). A reduction in the thickness of the stratospheric concentration of ozone allows a greater proportion of UVB radiation to reach the Earth's surface, and will generate an increase in UVB-related cancers. Although NMSC is not as serious as melanoma, it accounts for the majority of skin cancers.

Recognition of the problem

Scientist Richard Scorer of Britain's Imperial College was a respected environmentalist, but sided with industry on the safety of CFC's, claiming in 1975 that 'The only thing that has been accumulated so far is a number of theories' (Roan, 1989:61).

In spite of scepticism about the ozone depletion theory from some quarters, the case for limiting the production and emission of ODS is often viewed as a *cause célèbre* for international agreements. This is because it was one of the first cases of successful coordinated, international action on phasing out a chemical (CFCs were the first of the ODS to be banned) that was in widespread use, and that was shown to be causing an environmental impact on a global scale. The Montreal Protocol entered into force on 1 January 1989, and was recognised by Kofi Annan in 2003 as 'perhaps the single most successful international environmental agreement to date'. It went on to become the first international treaty to be universally ratified, on 16 September 2009, by 196 countries, and has shown demonstrable success in achieving its stated objectives. This means that the ozone layer should return to its pre-1980 levels sometime between 2050 and 2075 (UNEP, 2009a).

Figure 23.3 Region of exceptionally depleted ozone in the stratosphere over the Antarctic



Source: NASA/Goddard Space Flight Center Scientific Visualization Studio.

A study undertaken in 2009 attempted to predict the future that was avoided by the Montreal Protocol and by subsequent international agreements on ozone-depleting chemicals (Newman et al., 2009). The benefits of early action are starkly illustrated in the predicted 'World Avoided' ultraviolet (UV) radiation index compiled by that study (see Figure 23.4). This figure shows the impact of the increasing amount of harmful UV radiation that would have been permitted to reach the Earth's surface. Without international agreements to eliminate ODS production and emissions, the ozone layer could have reduced in thickness by as much as 67 % by 2065, with highly damaging consequences for humans and many other organisms.

Box 23.3 Benefits of early action on ozone depleting substances (ODS) (cont.)

Economic impacts

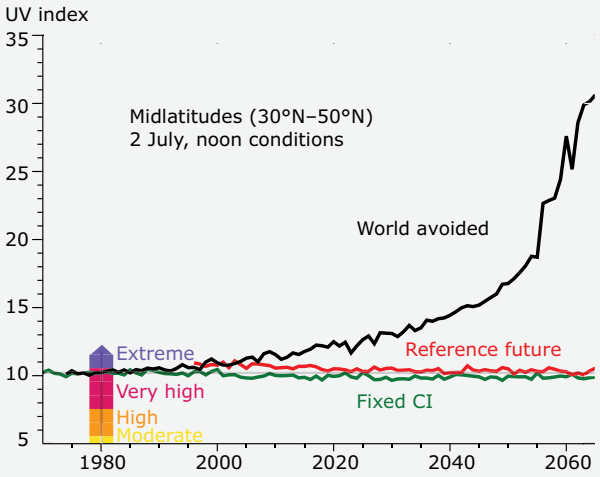
Health

Incidence of skin cancers in response to increased UV radiation are expected to peak about 60 years from exposure. Assuming prevention of a 48 % decrease in the ozone layer by 2050, UNEP (2009b) has estimated that more than 20 million skin cancers and 130 million cataract cases have been prevented globally as a result of the Montreal protocol.

The stabilisation of the ozone layer means that by 2050 annually about 47 000 skin cancer cases will be avoided in north-western Europe, although 14 000 additional cases of skin cancer are still to be expected as a result of the damage to the ozone layer that has already been done and the 60 year latency period (Slaper et al., 1998:83; Velders et al., 2001:8). 99.5 % of skin cancers are likely to be non-melanoma with a mortality rate of 1 %, while 0.5 % will be melanomas with a mortality rate of 24 %. The implication is about 500 fatalities avoided annually in north-western Europe towards the middle of the 21st century.

Assuming the same ratio between fatality reduction and other avoided UV-radiation effects (mainly health-related) as in US studies (Sunstein, 2007), these figures imply that annual benefits of early action from the Montreal Protocol are not less than EUR 3 billion for Europe. Scaling results for north-western Europe to all of the European Union must take into account higher exposure risks in southern Europe, with likely annual benefits of EUR 10–11 billion for EU-27.

Figure 23.4 The 'world avoided' UV index as a result of international agreement



Source: Newman et al., 2009.

Climate change benefits of early action

ODSs have had a considerable impact upon so-called 'radiative forcing', and therefore on global warming (Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the earth-atmosphere system). It is estimated that 13 % of the present total global warming effect is due to the release from year 1750 to 2000 of Halocarbons and ODSs (IPCC, 2007).

The *avoided* impacts of ODSs on climate change are substantial. The combined effect in 1990 was 7.5 ± 0.4 $GtCO_2$-equivalent/year, or about 33 % of the annual CO_2 emissions due to global fossil fuel combustion (IEA, 2009). If we assume — in the absence of a Montreal protocol — a 3 % annual increase in ODS and halocarbon production, the 2010 emissions would have amounted to ~ 14 $GtCO_2$-equivalent/year. In other words the Montreal protocol has over two decades saved the atmosphere for about 215 $GtCO_2$-equivalent in emissions. Assuming that ODS had not been regulated separately, but also were to be counted under the Kyoto Protocol, these emissions, that stem mainly from developed countries, should have been offset and could have represented a cost of about EUR 2 150 billion (assuming a price of EUR 10 per tCO_2-equivalent) — about 0.5 % of annual GDP of OECD countries over these two decades.

The CO_2-equivalent of ODS-reduction is bigger than cuts required by developed countries under the Kyoto Protocol. Important is also the time delay achieved in relation to climate change. It will take between 7 and 12 years for CO_2-emissions to increase by the amount of ODS abated with the Montreal Protocol. If considering the full reduction achieved since the 'early warning' scientists Molina and Rowland (1974) first called attention to the ozone layer break-down, as many as 30 to 45 years may have been gained (Velders et al., 2007). These estimates further underscore how early warning scientists must be attributed a role in curbing ODS-consumption being equally important to the Montreal protocol itself.

SCBA — social cost benefit analysis — to sweeten the pill (RMNO, 2008). The uptake of cost-benefit analysis has been most significant in the United Kingdom. And because the United Kingdom has promoted the extension of the method to EU regulations — with occasional support from other Member States — there are examples of formal requirements for cost benefit analysis in EU programmes. Findings from cost-benefit analysis are also referred to in impact assessments of new legislative proposals prepared by the Commission. There has been a rule in place for the past 15 years requiring a cost-benefit analysis as part of the screening of projects set to receive EU support under the Structural Fund programmes and a manual is available to guide these assessments, published by the European Commission (2008).

Obviously there are great methodological challenges in further expanding the use of cost-benefit analysis. However, there has also been some progress in these methodologies. For example, improvements in scientific knowledge and modelling techniques have helped to significantly influence the ratios of benefits to costs in favour of regulation.

Precautionary action can be justified by using credible estimates of the costs of inaction. The lead case illustrates that even if we have an understanding of only some of the benefits, making good use of the science base can be enough to prompt action. The nitrate case demonstrates that risk calculations can be useful and help prompt immediate action, even though the time-lag effects of exposure means that full proof will likely take decades to materialise. Finally, in the case of air pollution, making use of different estimates for mortality risk avoidance will help decision-makers to see that there are higher- and lower-bound estimates for the costs of inaction. Even if the lower-bound estimates are perhaps too conservative, with a bias towards health-effects, they will in many situations encourage more rather than less abatement effort. Reducing emission loads will also tend to bring relief for the intangible assets of biodiversity and nature.

Making the best use of environmental science and modelling helps to make environmental protection and precaution a priority. Producing cost estimates should not be left to economists alone, but should rather be seen as a starting point for a broader discussion, featuring also the relevant expertise in health, ecology, demography, modelling and science. Well-researched estimates, based on inter-disciplinary collaboration, can strengthen some of those scattered and diffuse interests, which during the ordinary processes of policymaking have difficulty making their voices heard.

References

ACCLPP, 2012, *Low level lead exposure harms children: A renewed call for primary prevention*, Report of the Advisory Committee on Childhood Lead Poisoning Prevention of the Centers for Disease Control and Prevention.

Ackerman, F., Massey, R., and Heinzerling, L., 2005, Applying cost-benefit to past decisions: Was environmental protection ever a good idea ?, *Georgetown Law Faculty Publications and Other Works*.

AEA Technology Environment, 2005, *Damages per tonne emission of $PM_{2.5}$, NH_3, SO_2, NO_X and VOCs from each EU25 member state (excl. Cyprus) and surrounding seas*, Service contract for carrying out cost-benefit analysis of air quality related issues in particular the Clean Air for Europe (CAFÉ) programme.

AMAP, 2011, Assessment of mercury in the Arctic, Oslo: Arctic monitoring and assessment programme.

Andersen, M.S., 2010, 'Miljøøkonomiske beregningspriser' (environmental economic unit prices), *Faglig Rapport 783*, Danmarks Miljøundersøgelser.

Andersen, M.S., Hansen, M.S., Carstensen, J., Kronvang, B., Andersen, H.E. and Thodsen, H., 2011, Monetary valuation with impact pathway analysis: Benefits of reducing nitrate leaching in European catchments, *International Review of Environmental and Resource Economics*, (5/3) 199–244.

ATSDR (Agency for Toxic Substances and Disease registry), 2011, Medical management guidelines: Sulfur Dioxide, Atlanta.

Axelrad, D.A., Bellinger, D.C., Ryan, L.M. and Woodruff, T.J., 2007, 'Dose-response relationships of pre-natal mercury exposure and IQ: An integrative analysis of epidemiologic data', *Environmental Health Perspectives*, (115/4) 609–615.

Barbosa, F., Tanus-Santos, J.E., Gerlach, R.F. and Parsons, P.J., 2005, 'A critical review of biomarkers used for monitoring human exposure to lead: Advantages, limitations and future needs', *Environmental Health Perspectives*, (113/12) 1 669–1 674.

Bell, M.L., Davis, D.L. and Fletcher, T., 2003, 'A retrospective assessment of mortality from the London smog episode of 1952: The tole of influenza and pollution', *Environmental Health Perspectives*, (112/1) 6–8.

Committee, 1997, *Japan's experience in the battle against air pollution: Working towards sustainable development,* Tokyo: Pollution-related health damage compensation and prevention association.

Diamond, P.A. and Hausman, J.A., 1994, Contingent valuation: is some number better than no number ?, *Journal of Economic Perspectives,* (8/4) 45–64.

De Roos, A.J., Ward, M.H., Lynch, C.F., Cantor, K.P., 2003, 'Nitrate in public water supplies and the risk of colon and rectum cancers', *Epidemiology, (*14) 640–649.

EEA, 2001, *Late lessons from early warnings: the precautionary principle 1896–2000*, Environmental issue report No 22, European Environment Agency.

European Commission, 2008, *Guide to cost-benefit analysis of investment projects,* Luxembourg.

Gidlow, D., 2004, 'In-depth review: Lead toxicity', *Occupational Medicine,* (54) 76–81.

Gould, E., 2009, 'Childhood lead poisoning: Conservative estimates of the social and economic benefits of lead hazard control', *Environmental Health Perspectives.*

Griffiths, C, McGartland, A and Miller, M, 2007, 'A comparison of the monetized impact of IQ decrements from mercury emissions', *Environmental Health Perspectives,* (115/6) 841–847.

Hammar, H. and Löfgren, Å., 2004, 'Leaded gasoline in Europe: Differences in timing and taxes', 192–205 in Harrington, W., Morgenstern, R. and Sterner, T. (eds), *Choosing environmental policy: Comparing instruments and outcomes in the United States and Europe*, Wash DC: RFF Press.

Heinzerling, L., Ackerman, F. and Massey, R., 2005, 'Applying cost-benefit to past decisions: was environmental protection ever a good idea?', *Admin Law Review,* (57) 155–192.

Hofstetter, P. and Hammitt, J.K., 2002, 'Selecting human health metrics for environmental decision-support tools', *Risk Analysis,* (22/5) 965–983.

Hylander, LD and Goodsite, ME, 2006, 'Environmental costs of mercury pollution', *Science of the Total Environment*, (368) 352–370.

IEA, 2009, *CO_2 emissions from fuel combustion — highlights,* International Energy Agency.

IPCC, 2007, *Safeguarding the ozone layer and the global climate system: Issues related to hydrofluorocarbons and perfluorocarbons*.

Japan Times Online, April 29, 2006, 'Koizumi issues official Minamata apology'.

Landrigan, P.J., 2002, 'The worldwide problem of lead in petrol', *Bulletin of the World Health Organization,* (80/10).

Lanphear, B.P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D.C., Canfield, R.L., Dietrich, K.N., Bornschein, R., Greene, T., Rothenberg, S.J., Needleman, H.L., Schnaas, L., Wasserman, G., Graziano, J. and Roberts, R., 2005, 'Low-level environmental lead exposure and children's intellectual function: An international pooled analysis', *Environmental Health Perspectives,* (113/7) 894–899.

Menke, A., Muntner, P., Batuman, V., Silbergeld, E.K., and Guallar, E., 2006, 'Blood lead below 0.48 umol/L (10 ug/dL) and mortality among US adults', *Circulation,* (114) 1 388–1 394.

Meyer P., Brown M. and Falk, H., 2008, 'Global approach to reducing lead exposure and poisoning', *Mutation research,* (659/1–2) 166-175.

Miranda, M.L., Anthopolos, R. and Hastings, D., 2011, 'A geospatial analysis of the effects of aviation gasoline on childhood blood lead levels', *Environmental Health Perspectives*.

Molina, M.J. and Rowland, F.S., 1974, 'Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone', *Nature,* (249/5460) 810–812.

Morgenstern, R., 1997, *Economic analyses at EPA*, Washington DC: Resources for the future.

NASA, 2010, *The world we avoided by protecting the ozone layer* (http:/earthobservatory.nasa.gov).

Needleman, H., 2004, 'Lead poisoning', *Annual Review of Medicine,* (55/1) 209–222.

Newman, P.A., Oman, L.D., Douglass, A.R., Fleming, E.L., Frith, S.M., Hurwitz, M.M., Kawa, S.R., Jackman, C.H., Krotkov, N.A., Nash, E.R., Nielsen, J.E., Pawson, S., Stolarski, R.S. and Velders, G.J.M., 2009, 'What would have happened to the ozone layer if chlorofluorocarbons (CFCs) had not been regulated', *Atmos. Chem. Phys,* (9) 2 113–2 128.

Nichols, A.L., 1997, 'Lead in gasoline', pp. 49–86 in R. Morgenstern (ed), *Economic analyses at EPA*, Washington DC: Resources for the future.

NSW (New South Wales) Government, 2006, Health factsheet methaemoglobinaemia (http://www.health.nsw.gov.au/factsheets/general/methae_fs.html).

NYT, 2011, 'EPA plans to revisit a touchy topic — the value of saved lives', 18 January 2011, *New York Times.*

OECD, 1977, *Environmental Performance Review: Japan*, Paris.

OECD, 2006, *Cost-benefit analysis and the environment: recent developments*, Paris.

OECD, 2008, *Costs of inaction on key environmental challenges*, Paris.

Olson, K., 2004, *Poisoning and drug overdose,* 4th ed., McGraw-Hill Medical.

Opinion, 1977, 'Million-dollar problem—billion-dollar solution?', *Nature,* (268/5616) 89.

Pizzol, M., Thomsen, M., Frohn, L.M. and Andersen, M.S., 2010, 'External costs of atmospheric Pb emissions: valuation of neurotoxic impacts due to inhalation', *Environmental Health,* (9) 9.

Pope, C.A., Thun, M.J., Namboodiri, M.M., Dockery, D.W., Evans, J.S., Speizer, F.E. and Heath Jr., C.W., 1995, 'Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults', *American Journal of Respiratory and Critical Care Medicine,* (151/3) 669–674.

Pope C.A., Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K. and Thurston, G.D., 2002, 'Lung cancer, cardiopulmonary mortality and long-term Exposure to fine particulate air pollution', *JAMA,* (287/9) 1 132–1 141.

Pretty, J., Brett, C., Gee, D., Hine, R., Mason, C., Morison, J., Rayment, M., van der Bijl, G. and Dobbs, T., 2001, 'Policy challenges and priorities for internalizing the externalities for modern agriculture', *Journal of Environmental Management and Planning,* (44/2) 263–283.

Reddy, A. and Braun, C.L., 'Lead and the Romans', *Journal of Chemical Education,* (87/10) 1 052–1 055.

Rive, N., 2010, 'Climate policy in western Europe and avoided costs of air pollution control', *Economic Modelling,* (27/1) 103–115.

RMNO, 2008, *Social cost-benefit analysis for environmental policy-making, Background study V14*, Raad voor ruimtelijk, milieu- en natuuronderzoek, The Hague.

Roan, S., 1989, *Ozone crisis: The 15 year evolution of a sudden global emergency*, New York: John Wiley.

Salkever, D.S., 1995, 'Updated estimates of earnings benefits from reduced exposure of children to environmental lead', *Environmental Research,* (70/1) 1–6.

Schnaas, L., Rothenberg, S.J., Flores M.F., Martinez, S., Hernandez, C., Osorio, E., Velasco, S.R. and Perroni, E., 2006, 'Reduced intellectual development in children with prenatal lead exposure', *Environmental Health Perspectives,* (114/5) 791–797.

Schwartz, J., 1994, 'Societal benefits of reducing lead exposure', *Environmental Research,* (66/1) 105–124.

Shimshack, J.P. and Ward, M.B., 2010, 'Mercury advisories and household health trade-offs', *Journal of Health Economics,* (29/5) 674–685.

Slaper, H., Velders, G.J.M. and Matthijsen, J., 1998, 'Ozone depletion and skin cancer incidence: a source risk approach', *Journal of Hazardous Materials,* (61/1–3) 77–84.

Smith, K.R., Jerrett, M., Anderson, H.R., Burnett, R.T., Stone, V.,Derwent, R., Atkinson, R.W., Cohen, A., Shonkoff, S.B., Krewski, D., Pope, C.A., Thun, M.J. and Thurston, G., 2009, 'Public health benefits of strategies to reduce greenhouse-gas emissions: Health implications of short-lived greenhouse pollutants', *The Lancet,* (374/9707) 2 091–2 103.

Spadaro, J.V. and Rabl, A., 2004, 'Pathway analysis for population-total health impacts of toxic metal emissions', *Risk Analysis,* (24/5) 1 121–1 141.

Spadaro, J.V. and Rabl, A., 2008, 'Global health impacts and costs due to mercury emissions', *Risk Analysis, (*28/3) 603–613.

Stern, N., 2007, *Stern review on the economics of climate change*, London: HM Treasury.

Sunstein, C.R., 2007, 'Of Montreal and Kyoto: a tale of two protocols', *Harvard Environmental Law Review,* (31) 1–65.

Taylor, M.P., Schniering, C.A., Lanphear, B.P. and Jones, A.L., 2010, 'Lessons learned on lead poisoning in children; Onehundred years on from Turner's declaration', *Journal of Paediatrics and Child Health,* (1) 440–1 754.

UNEP 2009a, *Key achievements of the Montreal Protocol to Date*, United Nations Environment Programme, Nairobi.

UNEP 2009b, 'Ozone Treaty press release', 16 September 2009, United Nations Environment Programme.

US EPA, 1985, Costs and benefits of reducing lead in gasoline: Final regulatory impact analysis, United States Environmental Protection Agency, National Center for Environmental Economics, Washington DC.

US EPA, 2010, Valuing mortality risk reductions for environmental policy: A white paper (draft), United States Environmental Protection Agency, National Center for Environmental Economics, Washington DC.

Van Grinsven, H.J.M., Rabl, A., de Kok, T.M., 2010, 'Estimation of incidence and social cost of colon cancer due to nitrate in drinking water in the EU: a tentative cost-benefit assessment', *Environmental Health,* (9) 58.

Velders, G.J.M., Slaper, H., Pearce, D.W. and Howarth, A., 2001, *Technical report on stratospheric ozone depletion*, RIVM report 481505011, Bilthoven.

Velders, G.J.M., Andersen, S.O., Daniel, J.S., Fahey, D.W. and McFarland, M., 2007, 'The importance of the Montreal protocol in protecting climate', *Proceedings of the National Academy of Sciences in the United States of America,* (104/12) 4 814–4 819.

Von Bahr, J. and Janson, J., 2004, *Cost of late action — the case of PCB*, TemaNord 556, Nordic Council of Ministers.

Weyer, P.J., Cerhan, J.R., Kross, B.C., Hallberg, G.R., Kantamneni, J., Breuer, G., Jones, M.P., Wei, Z. and Lynch, C.F., 2001, 'Municipal drinking water nitrate level and cancer risk in older women: The Iowa women's health study', *Epidemiology,* (12/3) 327–338.

WHO, 1994, Health and environmental effects of ultraviolet radiation; A Scientific Summary of Environmental Health Criteria, World Health Organization.

WHO, 2007, Nitrate and nitrite in drinking water, *Background document for development of WHO guidelines for drinking water quality*, WHO/SDE/WSH/07.01/16, World Health Organization.

World Bank, 2007, *Cost of pollution in China: Economic estimates of physical damages*, Washington DC.

24 Protecting early warners and late victims

Carl Cranor

Many *Late lessons from early warnings* chapters provide examples of early warning scientists who were harassed for bringing inconvenient truths about impending harm to the attention of the public and regulators. There is also some evidence that young scientists are being discouraged from entering controversial fields for fear of such harassment. In addition, where warnings have been ignored and damage has ensued, it has often proven difficult in the past to achieve prompt and fair compensation for the victims. Some ideas for reform, building on some current institutional models are explored here.

This chapter first explores the idea of extending whistleblowing laws to help encourage and protect early-warning scientists and others who identify evidence of impending harm. Complementary measures, such as greater involvement of professional societies and the use of recognition awards, as for example in Germany, could also be helpful.

Next, the chapter explores improved mechanisms for compensating victims of pollution and contamination. The chapter on the Minamata Bay disaster provides an extreme example of long delays in getting adequate compensation for the victims of methylmercury poisoning. It was almost fifty years, between 1956 and 2004, before the victims attained equitable levels of compensation and legal recognition of responsibility. Other case studies illustrate similar examples of long delays in receiving adequate compensation.

Options are examined for providing justice to any future victims of those emerging technologies such as nanotechnology, genetically modified crops and mobile phone use, which currently can provide broad public benefits but potentially at a cost to small groups of victims. The potential for widespread exposure and uncertain science could justify 'no-fault' administrative schemes that provide more efficient and equitable redress in situations where the benefit of scientific doubt would be given to victims. The use of anticipatory assurance bonds to help minimise and meet the costs of future environmental damage from large scale technologies is also explored.

A supplementary panel text describes cases of asbestos and mesothelioma, where the senior courts in the United Kingdom have developed innovative ways of dealing with both joint and several liability, and the foreseeability of subsequent asbestos cancers, after the initial recognition of the respiratory disease, asbestosis. Such legal developments in the field of personal injury could illustrate the future direction of long-tail liability in both environmental damage and personal injury.

Implementing a precautionary approach to managing new technologies requires, first and foremost, administrative laws aimed at detecting and addressing risks before they materialise into harms. But in addition to precautionary policies towards chemical, genetic and other technologies, additional legal tools can support the precautionary approach, better protecting public health and environment.

Since most statements of the precautionary principle emphasise acting on the basis of early warnings of threats to health and the environment and to minimise harm, at least two significant kinds of supporting laws should be considered.

First, in order to encourage the identification of impending threats to health or environment as early as possible, current whistleblowing laws could be extended to protect early warning scientists and others from harassment. Such people should feel free, and be free, to research and report early warnings without the threat of adverse actions that would discourage them.

Second, for those foreseeable and surprise events that cause future harm despite precautionary actions, measures could be taken to provide prompt and fair compensation without having to prove negligence by specific parties.

These two issues are explored below.

24.1 Encouraging and protecting early warning scientists and others

It is not hard to imagine situations where rules or personal risks could prevent potential 'whistleblowers' from sharing important information. Employees in academia, business or government might become aware of serious risks to health and the environment, but internal policies might pose threats of retaliation to those who report these early warnings. Private company employees in particular might be at risk of being fired, demoted, denied raises and so on for bringing environmental risks to the attention of appropriate authorities. Government employees could be at a similar risk for bringing threats to health or the environment to public attention, although perhaps this is less likely ([1]).

Several democracies in the developed world have implemented whistleblower laws and policies to foster and protect those who call attention to legal wrongs, often but not only regarding corruption. Such laws provide models for how to think about whistleblower protections in a precautionary world.

> 'Whistleblower protection laws are intended to make it safe for employees to disclose misconduct that they discover during the course of their employment. Indeed, when accompanied by other initiatives, such laws can actually help foster an environment that rewards and encourages whistleblowing' (Kaplan, 2001).

Countries that have constitutional guarantees of free speech can also assist in protecting public employees, in particular those who call attention to issues of public concern.

While some may praise whistleblowers for taking on their own companies or misconduct in government, others may regard them as disloyal, malcontents, grumpy employees, even bitter individuals who have been passed over for merits or promotions and are seeking to create problems. When they are regarded in this negative light, it becomes clear why there might be a need to foster and protect whistleblowing in order to encourage the revelation of misconduct, wrongdoing and harm, along with warnings that actions have occurred or are about to occur.

Some whistleblower protections in the United States

In the United States, the Civil Service Reform Act of 1978, as amended by the Whistleblower Protection Act of 1989 (WPA), provides some of these protections. As Kaplan (2001) explains:

1. The WPA 'makes it illegal to take or threaten to take a 'personnel action' against a federal employee because the employee has made a protected disclosure' where 'personnel action' is broadly defined.

2. This prohibition should be backed by sanctions for taking or threatening a 'personnel action' against a federal employee because the employee has a made a protected disclosure. This would be information that the employee 'reasonably believes evidences a violation of the

([1]) The US Union of Concerned Scientists has recently reported cases of government employees in food and other areas who have been restricted from speaking out in the past. There are now attempts to restore the integrity of science across the US government following an initiative from the administration (UCS, 2012).

law, rule or regulation, a gross waste of funds, gross mismanagement, an abuse of authority, or a significant and specific danger to public health or safety.' Moreover, such a disclosure 'need not prove ultimately accurate in order to be protected — it is enough if the person making it is acting in good faith and with an objectively reasonable belief in its accuracy.'

3. In the US, the Office of Special Counsel (OSC) enforces the whistleblower protection provisions of the WPA and has a great deal of independence from other government and private sector bodies to carry out its work.

4. The OSC has authority to correct an adverse personnel action or to prosecute any retaliation.

5. It also operates a 'secure channel', which government employees can use to report misconduct.

6. It is comparatively easy for a whistleblower to make a '*prima facie* case of retaliation'. It is sufficient that an employee's public disclosure be a 'contributing factor' to an adverse personnel action.

Following the recent financial crisis, the US Congress passed financial reform legislation that included protections for whistleblowers in order to improve early warnings of violations of securities laws (Harvard Law Review, 2011). The new law provides substantial bounties to people reporting information that the Securities and Exchange Commission (SEC) finds useful in identifying securities law violations, enhances protections for those providing the information, and establishes a two-tiered system for whistleblowers reporting to the SEC. The bounties can be 10–30 % of sanctions exceeding USD 1 million.

The law 'prohibits employers from discharging, demoting, suspending, threatening, harassing, or in any other manner discriminating against a whistleblower "because of any lawful act done by the whistleblower"' (Harvard Law Review, 2011). Protections for whistleblowers are greater for those who report directly to the SEC, but somewhat lesser for those who report to the company. These two tiers strongly encourage a person to report to the SEC rather than going to the company that has committed the violation. This could be a strength — boosting the hand of SEC enforcers, but discouraging local corrections for abuses — or a weakness, undermining internal compliance systems within companies.

Some whistleblower protections in the United Kingdom and South Africa

The United Kingdom's Public Interest Disclosure Act (PIDA) differs in some respects from the US approach (House of Commons, 1998). In the United Kingdom the PIDA governs both public and private employees, providing that 'a worker has the right not to be subjected to any detriment by any act, or any deliberate failure to act, done on the ground that the worker has made a protected disclosure.'

Based on 'reasonable belief', whistleblowers are protected if reporting criminal offenses, miscarriages of justice or that 'the health or safety or an individual, is being or is likely to be endangered.' There are defined channels by which a whistleblower may disclose violations but in the United Kingdom there is a preference for disclosing to the private employer or some public agency identified by the Secretary of State to hear such reports. Whistleblowers are at some risk if they go outside the recognised reporting channels (Kaplan, 2001).

In contrast to the US approach, the UK law encourages employers to specify internal procedures for disclosures and responses to them, but employees are not restricted to these. Moreover, there is no 'independent agency of the State to investigate or prosecute whistleblower complaints' as there is in the US (Kaplan, 2001).

In 2000, South Africa passed 'the Protected Disclosures Act', largely modelled on the UK's PIDA and covering both private and public employees. In addition to covering dismissals, demotions, involuntary transfers and suspensions, it goes beyond the US laws by 'explicitly including harassment and intimidation, as well as the refusal to provide an employment reference, or provision of an adverse reference as "occupational detriments"'. Reports of misconduct may be made to employers or a specified public agency, but there is no independent agency of the State to conduct investigations. The whistleblower has to invoke a court or tribunal for protection (Kaplan, 2001).

Whistleblower provisions have been enacted in some established democracies but many emerging democracies have been slow to institute them. In addition, countries with constitutional or other free speech protections appear to have a wider range of protections for those who identify and report wrongdoing (Kaplan, 2001).

In order for whistleblower provisions to function well employees must be aware of both statutory protections and the variety of channels through which disclosures or wrongdoing may be reported. The protections must be sufficiently effective to overcome employee reluctance to use them. In addition, government agencies and private entities must 'change their cultures, to make them receptive, rather than hostile, to employees who "rock the boat"' and this must be communicated from the top (Kaplan, 2001).

Desirable features of whistleblower laws

Whistleblower protections for those who report threats to the environment or public health from genetic, chemical or other technologies can supplement laws implementing the precautionary principle. Existing models suggest that such laws should protect public and private employees from adverse personnel actions, broadly construed.

Employees should be protected as long as they have a reasonable belief that private or government actions are a violation of the law or pose threats to the environment or public health. There should be a secure channel by which misconduct can be reported and it should be fairly easy for an employee to make a *prima facie* case that he or she has suffered retaliation. There should be an office with considerable independence from private or government bodies to provide protection and prosecute any retaliation. Finally, if a country desires to encourage whistleblowing more strongly, it could offer bounties amounting to some percentage of the fines issued against wrongdoers.

Panel 24.1 Better scientific support for early warning scientists?

David Gee

An early warning scientist is not the same as a whistleblower who reports on wrongdoing. However, the *Late lessons from early warnings* case studies have provided several examples of early warning scientists who, like whistleblowers, were harassed after issuing or publishing their views. Examples include Snow (in relation to his work on cholera); Selikoff (regarding asbestos); Henderson, Byers, Patterson and Needleman (regarding leaded petrol); Osakawa (regarding mercury); Putzai and Chapella (regarding GMOs); Schneider (regarding climate change); and several scientists in the French bees story. In addition there are others who wish to remain anonymous.

Other examples from beyond the *Late lessons from early warnings* case studies include public servants who have been prevented from speaking out on environment or health issues (UCS, 2012; Martin 1999 and 2008).

Generally, recognition that scientists were harassed seems to increase over time, alongside acceptance that the early warning has been vindicated by unfolding science. The luxury of such hindsight is of little use to harassed early warning scientists, however, who, unlike Nobel prize winners, need fairly immediate recognition for their 'inconvenient truth' and resulting personal difficulties.

The price of providing early peer group support to harassed early warning scientists could be that some warnings turn out to be false alarms. However, this may be seen as an acceptable price to pay for defending the rights of scientists to issue an early warning based on reasonably plausible evidence.

As we have seen, there are some legal precedents from the field of whistleblowing that could be used to help characterise the situations in which responsible early warning scientists would be encouraged and protected by their scientific peers. Relevant considerations include the following:

- the scientists have acted in good faith in drawing attention to threats to health and/or the environment based on evidence that they reasonably believe;
- the belief need not necessarily prove 'ultimately accurate' in order for them to be protected, (Kaplan, 2001);
- the early warning scientist suffers from some form of serious harassment, including personal attacks (distinct from scientific criticism) in the scientific literature and elsewhere; being prevented from speaking out, or publishing; removal from their scientific work; loss of contracts or funding; unreasonable difficulties in getting their science in the relevant literature; accusations of scientific misconduct; being by-passed for promotion; loss of their facilities or staff; and threats of legal action.

Panel 24.1 Better scientific support for early warning scientists? (cont.)

In contrast to whistleblowers, where the law is the main measure used in their protection, it would be more constructive if early warning scientists were encouraged from the outset by a culture within science that explicitly supported challenges to conventional scientific ideas and paradigms and the scientists who may suffer as a result of producing the challenges. There is a long history of scientific and other dissenters, which illustrates their frequent value to societies (Sunstein, 2005; Mercer, 2010).

It may be asking too much of individual scientists, whose lifelong work is challenged by an early warning scientist, to respond positively to the challenge. It would be reasonable, however, to expect more independent professional associations of scientists, who have the integrity of science as a whole to uphold, to produce explicit policies that encourage early warning scientists and defend them if they are harassed.

Early warning scientists would be further encouraged if there were a European award to an early warning scientist who had produced a reasonably credible challenge to conventional science and who subsequently suffered harassment.

Such an award would follow the precedent of rewards to successful whistleblowers, which began with a law against lead in alcohol production in the USA in the 18th century (see Chapter 3) and which continue today under US financial regulations.

The award would need to be made by an authoritative and independent scientific body of scientists, free from direct bias (i.e. their own scientific work would not be challenged by affording credibility to the early warning science).

An interesting legal view of such 'intellectual bias' comes from a World Trade Organization case in which scientists acting as expert witnesses were asked to review science that was critical of their own work. The WTO Appellate Body considered that as 'coauthors' of the JECFA reports that were being criticised, they 'cannot be considered to be independent and impartial in these circumstances, because this would amount to asking them to review and criticise reports that are their own doing' (WTO, 2008).

An appropriate title for such an award could be 'The Henrik Ibsen award for early warning scientists' in recognition of Ibsen's play, 'An enemy of the people' which concerns the harassment of an early warning public health doctor. The harassed Chisso company doctor in the Minamata chapter of the present volume of *Late lessons from early warnings*, like many others in similar situations drew support from reading that Ibsen play.

An existing award that could provide some relevant lessons is the German Whistleblower Award, which honours individuals who have exposed grave abuses, dangers or aberrations in their professional field for the public good. It is awarded by The Federation of German Scientists (VDW/FGS) and the German section of the International Association of Lawyers Against Nuclear Arms (IALANA). info@vdw-ev.de / info@ialana.de.

In addition to possible legal remedies, early warning scientists could receive greater support from scientific communities (see Panel 24.1).

24.2 Providing compensation in a precautionary world

If we have precaution, do we need compensation?
How necessary are compensation policies in a legal system committed to precaution in protecting health and the environment? Compensation might seem unnecessary in a world guided by precautionary approaches. Effective precautionary approaches would result in fewer wrongs to right; wholly successful policies might not leave any.

In reality, of course, flawless implementation of precautionary approaches is unattainable. Compensatory schemes are needed to address harms that occur despite precautionary efforts.

Harms can also arise because society accepts certain risks, which benefit society as a whole but may result in harm to individuals. For example, we use lead or cadmium in batteries and other electronic devices despite the hazards to people and the environment. Alternatively, accepting one risk of

harm potentially mitigates other, more serious dangers to human or environmental health. The use of some pesticides is an example of such a risk-risk trade-offs. Even if such harms do not involve wrongful acts by individuals or companies, justice arguably demands that society compensate those adversely affected

In addition, there may continue to be less visible threats to health and the environment. For instance, substances that contribute to disease during early human development can trigger subtle diseases or dysfunctions that can be difficult to detect via human studies. Some will have extremely long causal tails, delaying the manifestation of disease by decades. Some will be comparatively rare. For example, early or mid-life exposures to substances such as the pesticide paraquat or the industrial degreaser trichloroethylene (TCE) may hasten the early onset of Parkinson's disease, as shown by animal and human studies (Cranor, 2011). Other substances may pose long-delayed risks to wildlife or the broader environment, as has been seen in the Arctic (Cone, 2005).

Genetically modified plants may cause subtle genetic or other changes in vegetation or the environment that may not be immediately perceptible, or that will only be revealed over a longer period of time. For example, there have been proposals to use transgenic plants to extract organic mercury from the soil and volatilise it into elemental mercury (National Research Council, 2002). While this might be of some benefit at a local level, on a larger scale this proposal could easily have long-term adverse environmental and health consequences. Concentrations of atmospheric mercury would probably increase in local areas and then be deposited further away into aquatic or terrestrial ecosystems via precipitation and condensation. Once there, it would again be converted into more toxic organic mercury, although in a different location. This would add to organic mercury from other sources, exacerbating existing effects (National Research Council, 2002). Decision-makers must clearly be alert to such long-term, subtle environmental consequences of new technologies.

Finally, it is worth noting that imposing an obligation to compensate those harmed by technological hazards can also help deter firms from undertaking harmful activities.

Compensation systems

There are different rationales for compensation. One comes from the tort law. As Priest (2003) explains: 'Tort law is designed to deal with harms inflicted by some identifiable person who was in a position to have prevented the harm'. The tort system shifts the costs of injuries to parties judged to be responsible, sometimes 'at fault' for the harm, 'in order to create incentives to reduce the level of harm suffered in the society'. It awards full damages to injured parties in order to ensure that the full costs of the legal violation are paid by the tortfeasor and to provide some degree of deterrence.

In contrast, **insurance** addresses 'losses that cannot realistically be prevented'. Typically private insurance is funded by parties seeking to protect themselves from future costs and placed into 'self-supporting risk pools in ways that serve to reduce effective risks while amassing resources to compensate those who ultimately suffer losses'. **Government insurance**, another form of risk sharing, is ordinarily 'provided for more generalised societal risks for which no, or less of a, market exists, such as the risks of unemployment or disaster' (Priest, 2003).

Contrasted with all of these, but somewhat similar to tort law, are systems of **compensatory reparations**. Reparations presuppose that one person has acted wrongly, causing harm to another person who deserves compensation as a consequence (Boxill, 2011). The best reparations would also include an acknowledgement by the wrongdoer of the wrongdoing in order to help restore relationships severed by the wrongful act ([2]). Institutionalising acceptance of wrongdoing presents difficulties, however, and there is likely to be greater success in securing compensation for injured parties if it is not required.

The existing institutions discussed below do not always carefully distinguish these different dimensions of restitution. The central idea, however, is to provide some substantial degree of recompense to those who have suffered losses as a result of new technologies.

One ideal would be to ensure that the full social costs of a technology are incorporated into the costs of the activity (removing negative externalities), or at least to ensure that the costs are not left to fall on innocent bystanders or the environment. However,

([2]) As noted in Chapter 5, victims of methylmercury poisoning in Minamata, Japan, have sought such acknowledgement but have not secured it.

not all compensatory approaches accomplish the first goal. For example, the creator of a technology that causes harm may not be have acted wrongfully according to the requirements of tort law or compensatory reparation systems.

Guidance for compensation in a precautionary world

The above discussion suggests the outline for compensatory approaches in a precautionary world:

1. Successful precautionary policies should reduce the need for compensation.

2. Compensatory approaches should seek to minimise any harm as quickly as is institutionally reasonable and to shorten its duration, if possible.

3. Some past environmental, health and new technological issues suggest that compensation is needed to address difficult situations such as long-tailed, less visible, low probability, and subtle consequences of a technology. These could be long-tailed in two senses: both highly unlikely and possibly years into the future.

4. Any reasonable compensation should also be combined with an adequate deterrence mechanism to discourage firms from negligence or recklessness toward public health or the environment.

5. Finally, in some countries with single-payer health systems that provide medical care to all citizens, compensation for injured people would be less than under medical systems with private insurance. Nonetheless, there would still be a need to compensate for income loss, personal suffering, losses of loved ones, and other non-medical losses.

What compensatory 'institutions' or policies might be adopted for a precautionary world to set matters right, once people or the environment have been harmed? Of those compensatory approaches, which might be most compatible with a precautionary approach towards people and environmental resources?

With these questions in mind, the strengths and weaknesses of several compensatory approaches are assessed below: traditional personal injury law, workers' compensation, and individual compensatory schemes tailored to particular classes of potential harms such as the US Vaccine Injury Compensation Program and the UK's radiation compensation programme. In addition, general no fault compensatory arrangements like those used in New Zealand are considered, and flexible assurance bonds instituted upfront to provide compensation if technological risks materialise.

24.2.1 Tort or personal injury law

Tort or personal injury law is a major institution in the US and the United Kingdom (with analogues in other countries). It aims to provide compensation for injuries that people suffer because of the conduct of others. In bringing a tort action, a party (the plaintiff), who believes another party (the defendant) has caused him or her harm, must show that defendant breached a legal duty, that the plaintiff suffered a legally compensable injury, and that defendant's breach was the cause in fact and the legally proximate cause of the injury. Each element of the cause of action must be established by the preponderance of the evidence — the balance of the quality and quantity of evidence must favour the plaintiff.

The duty that the defendant breached in most cases is a duty in negligence — to take reasonable care that one's actions do not cause legally compensable injuries to others. In the US, tort duties in strict liability (liability without fault) exist for products, ultra-hazardous activities and trespass. Under strict liability a plaintiff need only show that the defendant's action caused and was the proximate cause of a plaintiff's injuries. A plaintiff need not show lack of reasonable care by the defendant.

When torts came into prominence in the 19th century, it was quite cramped and restricted in principle at the outset and quite limited in application in achieving compensation goals. Nineteenth century courts never considered holding defendants accountable in strict liability, instead basing liability on 'moral fault,' interpreted as negligence. Defendants were also provided a number of defences that greatly limited many tort actions for harm caused by railroads or factories during the industrial age, reducing the number of injuries entitled to compensation. Courts were concerned that more extensive tort liability would too greatly burden enterprises; and they had a suspicion of juries, who might be overly sympathetic to injured parties. Both continue in current debates (Friedman, 1985).

As the tort law developed, some of these liability-limiting features were moderated. Strict

liability became the basis for some legal actions: for harm caused by ultra-hazardous activities and for products liability. Proximate causation rules were liberalised. In the early 20th century workplace torts largely disappeared in favour of a government-managed workers' compensation programme designed to expedite compensation, remove long, costly disputes, and provide a more consistent legal framework for addressing workplace injuries (Friedman, 1985).

Doctrines more favourable to plaintiffs continued to develop until about 1980. Various cause-in-fact rules were adopted to ease the burden on plaintiffs in establishing causal claims, recognising the multifactorial nature of causation (Anderson v. Minneapolis, St. Paul & S. St. M.R.R. Co., 1920; Summers v. Tice, 1948; Sindell v. Abbott Laboratories, 1980). Doctrines of joint and several liability better ensured that plaintiffs received compensation from some defendant to an action.

About this time, firms required to defend tort suits, with support from some legal scholars, began efforts to roll back doctrines that had eased the burden on plaintiffs. At the same time, other scholars argued that the tort law had never served well to express moral outrage about wrongs (likely never its aim), poorly compensated plaintiffs and did not function especially well to deter harmful conduct (Abel, 1988).

Defence arguments yielded some success in the United States during the late-1980s and early-1990s. Some jurisdictions limited compensation, especially for pain and suffering. Some sought to limit joint liability. And, there was considerable pressure to ensure high standards for scientific evidence in cases requiring it.

As a consequence, the US Supreme Court intervened, ultimately invalidating a long-standing rule concerning the admissibility of scientific testimony. The Court had initially seemed to liberalise admissibility rules for experts in Daubert v. Merrell-Dow Pharmaceuticals (1993). However, as that decision was implemented by lower courts and expanded by two later Supreme Court decisions (General Electric v. Joiner (1997) and Kumho Tire v. Carmichael (1999)), in many jurisdictions it substantially burdened experts, especially those for plaintiffs (Cranor, 2006). Some state and federal circuits are especially onerous (Merrell Dow Pharmaceuticals, Inc. v. Havner, 1997). Although in principle these rules impartially apply to both plaintiffs and defendants, in reality they asymmetrically hamper plaintiffs, who bear the burden of proof to establish the key elements of a tort.

This series of decisions reduced plaintiffs' access to the law because lawyers must invest greater resources upfront to ensure that experts have good scientific foundations for testimony, which in turn means they only take cases they are more certain to win. This development likely reduces somewhat any deterrent effect of tort law (Cranor, 2006).

Too often judicial interpretations of the admissibility of scientists erected unscientific barriers against expert testimony (Cranor, 2007 and 2008b). Recently, however, a decision from the US First Circuit Court of Appeals has marked a change. In that circuit, with jurisdiction over about one-twelfth of the US, scientists may now use in the courtroom the same kinds of arguments that they would use in the lab to draw scientific conclusions. In addition, there is no priority of evidence for cancer causation, such as human epidemiological evidence (Milward v. Acuity Specialty Products, Inc., 2011). This decision removes some judicially created unscientific barriers to expert testimony.

In large measure current US tort law does not compensate injured parties well or quickly. They bear the initial burden of proof to establish legal violations, injuries and causation. When scientific or technical evidence is needed, this increases the hurdles. In some US federal jurisdictions plaintiffs must have human epidemiological evidence showing that toxic exposures double the relative risk of disease from which a plaintiff suffers, a further barrier because of the insensitivity of epidemiological research. In some jurisdictions compensation is capped at a sufficiently low level that it is inadequate for some injuries. Even when plaintiffs are successful, resolution can take considerable time.

Milward v. Acuity Specialty Products was filed in 2007 and stopped by the trial judge for inadequate scientific testimony in 2010. It was reinstated by the First Circuit Court of appeals in 2011 with many of the original twenty-two defendants settling. As of 2012 one defendant continued to seek a jury trial to conclude the issues. This case involves a single plaintiff (but many defendants) and in this respect may be typical of many tort cases.

Class actions involving many plaintiffs and sometimes many defendants are more difficult and can take longer to resolve. However, once there is a sufficient record of injury types, as with asbestos, and a long history of litigation,

subsequent compensation disputes will generally be settled much more quickly, often without trial. In addition, class action cases can reach a point at which the issues are clear and there is no need to litigate compensation for each plaintiff. At that time, defence and plaintiff attorneys, perhaps with encouragement from the judge, agree to a 'settlement matrix' — a classification system for groups of plaintiffs with similar exposures, adverse health outcomes and possible confounding factors, e.g. health status or smoking. The matrix enables comparatively easy classification of each plaintiff to receive greater or lesser compensation depending on the circumstances for the injuries suffered. In this respect, some tort law settlements can resemble the classification of injured parties under the compensation schemes described below, such as worker compensation or vaccine injury compensation.

In addition to the shortcomings of the tort system outlined above, it is essential to note that when there is clear harm to people, injured parties rarely bring legal cases to set matters right. For instance, Saks (2000) observes that in cases of clear medical malpractice just 4 % or fewer of injured parties even approach a lawyer to consider redress.

Based on the above, existing US tort law appears to be a poor legal model for providing rapid and adequate compensation for those who have been wrongly injured by the actions or products of others. Tort law persists but its achievements fall far short of its goals.

Battery and trespass are two other causes of action in the US tort system that could provide some compensation for citizens, short of people being actually harmed. Battery is the 'foundational tort cause of action. It protects bodily integrity and individual autonomy, creating the essential status and space for social interactions' (Lyndon, 2012). The idea is that by giving citizens a cause of action for offense against them or for violation of bodily integrity without their consent, this lessens the chances of retaliatory harm needing criminal intervention; historically it was a means of helping to keep the King's peace in the United Kingdom.

To establish a battery a plaintiff must show that 'the defendant committed a voluntary act with the intent to cause a wrongful [offensive or harmful] contact and the contact occurred.' Intent is widely construed for this purpose and it applies to the contact only; one need not intend offensiveness or harm (Lyndon, 2012; Cranor, 2011). For intentional invasions of one's body by potentially harmful chemical substances without consent that one would reasonably regard as offensive, one could bring a battery cause of action. A special advantage of battery compared with the main body of tort law is that one need not show harm as the result of the invasion, offensive contact is sufficient. Consequently, if one's bodily integrity has been invaded by potentially harmful substances in a manner one would reasonably regard as offensive, whether or not one has been harmed and before one could even show harm, one potentially has a cause of action in battery.

Trespass is also a vindication of a legal right against invasion. What remains of early trespass law largely concerns property but also applies to invasions of individuals. If someone enters property or causes molecules, particles, or toxic substances to enter property without 'authorization' or without permission, the person has trespassed on the property. Trespass also applies to violations of the integrity of persons, e.g. as when blasting trees injure a party on a public highway (Cranor, 2011). Both battery and trespass are founded on deep considerations concerning the integrity of one's person (or property) and 'rights over aspects of one's life'. Without doing harm one can be accountable for either battery or trespass and merit compensation. Compensation for battery would consist of 'Proof of the technical invasion of the integrity of the plaintiff's person by even an entirely harmless, but offensive, contact [which] entitles him to vindication of his legal right by an award of nominal damages, and the establishment of the tort cause of action entitles him also to compensation for the mental disturbance inflicted upon him' (Cranor, 2011).

A larger number of citizens could potentially bring battery or trespass causes of action than could bring actions in torts for harm caused by toxicants. This might better facilitate safety testing and better deter invasions by potentially harmful substances than would successful tort suits alleging (and even proving) harm. Battery and trespass would likely be much quicker and easier to resolve than would tort suits for harm. Compensation for each individual invaded in a battery/trespass action would likely be much less than for each individual harmed in a typical tort action, but total compensation paid out by a company that caused the invasion (or harm, respectively) could be substantial.

One aspect of the tort law, whether for actions for harm or battery/trespass, is quite important both in supporting health protections and providing compensation for plaintiffs. This is a pre-trial stage called 'discovery'. During discovery each litigant in

the dispute can interrogate the other party about information it may have about the background of the dispute, try to determine what legal issues are or could be easily agreed upon, request documents related to the issue, and conduct depositions (questioning of witnesses on the issues). This process can reveal a good deal of information about a case that might expedite settlement or narrow issues. It can also serve the wider public good, by revealing hidden data about adverse health effects, decisions made by responsible people that contributed to harm, policies that might have exacerbated problems and so on. If information unearthed during discovery is publicised, as it has been for asbestos, lead, and vinyl chloride in the US, it can alert public health officials to other problems, issues meriting further investigation, scientists who have acted without integrity, or even other serious legal wrongdoings (Brodeur, 1983; Markowitz and Rosner, 2002).

In a legal system that greatly emphasised precautionary policies toward risks and harms, tort law with its emphasis on showing harm would be a poor compensatory model simply because bringing a successful tort action is normally burdensome and slow. This would greatly slow efforts to reduce harm and clean up environmental contamination. Tort actions for battery/trespass would be less burdensome and slow, but lesser compensation for each individual would result; total compensation paid out could be substantial.

Of course, tort law can be modified; it is not set in stone. For instance, there are some developments in the tort system of the United Kingdom that merit attention because they may expand the range of compensation available to plaintiffs for injuries suffered from some kinds of environmental exposures. For asbestos-caused mesothelioma possibly resulting from exposures due to the activities of two or more defendants, a plaintiff need not rule out other possible causes (because all or virtually all mesothelioma is caused by asbestos exposure). Also, once liability has been established for particular defendants, all defendants must pay full compensation for the mesothelioma-related injuries. Other court decisions have applied the same principle to dermatitis caused by coal dust (discussed below).

Just because medical science cannot determine which of several liable defendants' asbestos fibres caused plaintiff's injuries does not bar recovery for mesothelioma. In short, 'where there are multiple potential tortfeasors ... in the case of an 'indivisible injury' such as mesothelioma, **any tortfeasor** could be liable for the whole of the injury once liability has been established' (McIntyre, 2004 (emphasis added)). UK courts treat asbestosis (which also results from asbestos exposures) differently: each liable defendant in a group need not pay for the full costs of the disease but only for the portion of time plaintiff had asbestos exposures at their facilities (McIntyre, 2004).

A second UK innovation concerns foreseeability for harm from an asbestos facility to those outside the plant boundaries. Where a defendant should have reasonably foreseen a risk of pulmonary injury, not necessarily mesothelioma, it has been found liable for mesothelioma in people who reside near to asbestos plants (see Panel 24.2.). Generalising from this, it suggests that companies might be liable not merely for known toxic injuries to employees but also for other types of harm to local residents of a type that emerged after the initial exposure (McIntyre, 2004).

24.2.2 Alternatives to the tort system

Workers' compensation

The tort system's shortcomings in addressing compensation for **occupational** injuries and illnesses led to the development of an alternative compensatory arrangement. Under tort law, employees seeking compensation historically bore the burden of proof to show that employment caused an injury and that the employer was negligent. Employers had an incentive to delay legal proceedings because injured employees probably had more limited means to support themselves, to secure medical care and to bring legal actions. Such suits were slow to resolve and unpredictable, and damages were often inadequate. Employees were often afraid to sue their employers, and witnesses among fellow workers were often difficult to find (Franklin, 1979).

Workers' compensation programmes were implemented as an alternative to torts for employees. They hold employers liable without fault for injuries suffered by employees in the course of and arising out of their employment. Employees 'exchange their common law damage actions for smaller but more reliable recoveries whenever they [are] hurt on the job even if they [are] at fault and the employer [is] not' (Franklin, 1979). The discussion that follows provides the general outlines of workers' compensation within various states in the United States, since this is a state, not a federal issue.

Panel 24.2 Liability for asbestos-related illness: redefining the rules on 'toxic torts'

Owen McIntyre

In recent years litigation over diseases resulting from exposure to asbestos has led to the progressive development of UK common law principles as they apply to two issues that have traditionally proven very onerous for plaintiffs claiming for 'toxic torts' (Cranor, 2006). These are the burdens of establishing the necessary causal link between an activity and disease and of establishing that harm that only becomes apparent long after the period of exposure, when scientific understanding of the risks may have been less developed, ought to have been reasonably foreseeable. Considerations of justice and injustice played a major role in each of these innovative developments in tort cases on asbestos-induced mesothelioma.

The UK House of Lords has recently ruled that the traditional 'but for' test for causation need not apply in mesothelioma ([3]) claims entered by employees who suffered periods of exposure to asbestos with more than one employer and where medical science cannot prove who among a number of employers caused the condition ([4]). This decision effectively creates joint and several liability whereby the claimant will be entitled to recover damages in full against each defendant.

In addition, and with strong implications for the precautionary principle, the English Court of Appeal ruled in 1996 that liability **arose in respect of exposure to asbestos resulting in mesothelioma despite the fact that the disease was not known to medical science at any time** during the relevant period of exposure ([5]). The Court reached this decision by employing a broad concept of injury for the purposes of establishing reasonable **foreseeability**. This development is significant in light of the emphasis placed on the requirement of foreseeability in environmental claims by the House of Lords decision in Cambridge Water Co. v. Eastern Counties Leather ([6]).

Causation

Establishing causation in toxic tort actions has long proven a difficult and even insurmountable task. The Scottish case of Graham and Graham v. ReChem ([7]) provides an extreme example of the practical problems which can be involved in establishing causation in such cases, involving an action in negligence and nuisance against the operator of a hazardous waste incinerator by local farmers for alleged damage to their cattle. The case lasted for 896 hours in court, spread over 198 days, and involved 80 lay witnesses and 21 expert witnesses on such issues as veterinary toxicology, agricultural accountancy, incinerator design, dioxin formation, pollution dispersion, analysis of trace organics and meteorology. The defendant's costs were estimated at GBP 4.5 million and the cost to the Legal Aid Board at GBP 1.5 million (see Wooley et al., 2000). Ultimately, the case failed on the issue of causation as there were other possible explanations of the cattle's injuries.

The cancer mesothelioma is classified by the UK courts as an 'indivisible' disease, as distinct from the respiratory disease, asbestosis, which is 'divisible' or cumulative. In the case of asbestosis, once the threshold for exposure is exceeded, all inhaled fibres are considered to contribute proportionately and progressively to lung dysfunction. The 'indivisibility' of mesothelioma creates obvious difficulty for a plaintiff mesothelioma victim who has been negligently exposed to asbestos by a number of defendants, usually successive employers, in terms of establishing causation.

In Fairchild, Curtis J. refused recovery at first instance to the estate of a mesothelioma victim suing two former owners of buildings containing asbestos in which he had worked ([8]). The Court found that there was no evidence of significant differences between the respective levels of exposure and was 'unable to establish on the balance of probabilities that the breaches of duty by either defendant were a cause or a material contribution to the deceased's mesothelioma'.

([3]) Mesothelioma is cancer of the lining of the lung or stomach. See the chapter on asbestos in Volume 1 of *Late lessons from early warnings* (EEA, 2001).
([4]) Joined cases Fairchild v. Glenhaven Funeral Services Ltd, Fox v. Spousal (Midlands) Ltd, and Matthews v. Associated Portland Cement Manufacturers (1978) Ltd and others, (2002), UKHL 22, NLJ Law Reports, 28 June 2002. See also, Morgan (2002).
([5]) Unrep. 17 April 1996. See further, McIntyre (2004).
([6]) (1994) 1 All ER 53 (H.L.)
([7]) (1996) EnvLR.
([8]) QBD, 1 February 2001.

Panel 24.2 Liability for asbestos-related illness: redefining the rules on 'toxic torts' (cont.)

However, a mere five months after Curtis J.'s decision in Fairchild, the English High Court reached a very different conclusion on very similar facts ([9]). Where a mesothelioma victim sued two of 15 employers who had exposed him to asbestos during the course of his working life, Mitting J., relying on the 1972 decision of the House of Lords in McGhee ([10]), justified his award of full damages against both defendants stating: 'The claimant was exposed by each defendant and by both defendants, to asbestos fibres, in quantities sufficient greatly to increase his risk of contracting mesothelioma.'

This followed the earlier ruling of Philips J. in a 1987 case ([11]) where he stated:

'Whether the defendants' breaches of duty merely added to the number of possible initiators of mesothelioma within the lungs of Mr Bryce, or whether they also produced a cumulative effect on the reduction of his body's defence mechanism, they increase the risk of his developing mesothelioma. He developed mesothelioma. Each of the defendants must accordingly be taken to have caused the mesothelioma by its breach of duty.'

The House of Lords later judgment in Fairchild relaxed the traditional test for establishing causation where there are multiple potential tortfeasors, holding that, in the case of an 'indivisible injury' such as mesothelioma, any tortfeasor could be liable for the whole of the injury once liability has been established. The House of Lords relied on its earlier decision in McGhee where it held that an employer who causes an indivisible disease such as dermatitis through exposure, only some of which is negligent, shall be liable in full for that injury.

The Lords stressed in McGhee that theirs was a 'common sense' understanding of causation having regard to the circumstances of such cases. According to Lord Reid:

' … it has often been said that the legal concept of causation is not based on logic or philosophy. It is based on the practical way in which the ordinary man's mind works in the everyday affairs of life. From a broad and practical viewpoint I can see no substantial difference between saying that what the respondents did materially increased the *risk* of injury to the appellant and saying that what the respondents did made a material *contribution* to his injury' (emphasis added).

Lord Hoffman stated that 'I think it would be both inconsistent with the policy of the law imposing the duty and morally wrong for your Lordships to impose causal requirements which exclude liability'.

Lord Hoffman approved the test for causation proposed by the Supreme Court of California in Rutherford v. Owens-Illinois Inc., stating that 'the causal requirements of the tort were satisfied by proving that exposure to a particular product was a substantial factor contributing to the … risk of developing cancer'.

Lord Bingham stated that '… such injustice as may be involved in imposing liability on a duty-breaking employer in these circumstances is heavily outweighed by the injustice of denying redress to a victim'.

Foreseeability of the 'surprise' disease of mesothelioma

The unique characteristics associated with the disease of mesothelioma have also resulted in the English courts taking an innovative approach to the issue of foreseeability of damage for the purposes of liability. The disease can develop from a very short period of exposure, even from a single instance of exposure but only manifests itself many years after exposure. According to statistics published by the insurer Munich Re, the average latency period (i.e. from first exposure to diagnosis of the cancer) for asbestos-related mesothelioma is 34 years ([12]) and epidemiology suggests that it is so rare for the latency period to be less than ten years that exposures within ten years of diagnosis may be excluded as causal (see Miller, 2002).

([9]) Matthews v. Associated Portland Cement and British Uralite PLC, QBD, 11 July 2001. Indeed, Dr Rudd, the principle expert witness in Fairchild, also acted in Matthews giving substantially similar evidence. See Miller (2002).
([10]) McGhee v. National Coal Board (1972) 3 All ER 1008, where it held that an employer who causes an indivisible disease such as dermatitis through exposure, only some of which is negligent, shall be liable in full for that injury.
([11]) Bryce v. Swan Hunter Group plc and others (1988), 1 All ER 658.
([12]) Munich Re, Employers Liability Handbook. See further, Buckley, supra, n. 1, at 192.

Panel 24.2 Liability for asbestos-related illness: redefining the rules on 'toxic torts' (cont)

In the joined cases Margereson v. JW Roberts Ltd and Hancock v. JW Roberts Ltd, ([13]) the plaintiffs sued an asbestos manufacturer after having contracted mesothelioma due to the defendant's extensive asbestos contamination of the district of Armley in Leeds where both plaintiffs had lived as children. Both sued in negligence and strict liability ([14]) and/or nuisance, though only liability in negligence was considered by the court. It was never disputed by the defendant that the steps taken by them to mitigate the problems of asbestos dust contamination were woefully inadequate. At trial, Holland J. found for the plaintiffs despite the fact that at no material time was mesothelioma a concept known to medical science.

The defendant appealed on the ground that there was no culpable lack of foresight on their part as they did not know and had no reason to believe that the risk of mesothelioma existed.

The Court of Appeal rejected the appeal stating that liability would arise where the applicant should reasonably have foreseen a risk of some pulmonary injury, not necessarily mesothelioma, and, that the damage occurred at a time when the applicant was on actual or constructive notice as to the potential pulmonary damage that exposure to asbestos could cause.

The Court also considered whether any distinction could sensibly be made between employees working within the factory and local residents. It asked 'did the factory wall pose such a barrier that risk of injury to persons on the other side … amount at worst to no more than a "mere possibility which would never occur to the mind of a reasonable man"?' and agreed with the trial judge that if the conditions outside the factory are not materially different to those giving rise to a duty of care within, there is 'no reason not to extend to that extramural neighbour a comparable duty of care'.

Lady Justice Hale has elsewhere ([15]) stated:

'The point which impressed the [trial] judge was the certain knowledge that asbestos dust was dangerous and the absence of any knowledge, and indeed any means of knowledge, about what constituted a safe level of exposure. … But just as courts must beware using such later developments to inflate the knowledge which should have been available earlier, they must beware using it to the contrary effect. The fact that other and graver risks emerged later does not detract from the power of what was already known …'

It remains to be seen whether this decision has implications beyond personal injury actions ([16]) and whether the courts are prepared to apply a less onerous test of foreseeability in cases of environmental damage generally. Where any particular class of environmental damage was foreseeable, liability might arise for any other type of damage in that class which arises much later. Several of the case studies in volume 1 of *Late lessons from early warnings* (EEA, 2001) and the present report demonstrate that much harm arises after the first wave of harm, e.g. with PCS, mercury, CFCs, benzene and radiations. If the courts were to examine foreseeability in the context of broad classes of damage, the test of foreseeability (seen by many commentators as one of the factors responsible for tort's failure to compensate for historic pollution), would effectively be relaxed. The test may now relate to the foreseeability of some relevant damage.

([13]) *The Times,* 17 April 1996.
([14]) Rylands v. Fletcher (1868), L.R. 3 H.L. 330.
([15]) Shell Tankers UK Ltd. v. Betty Irene Jeromson (2001), EWCA Civ 101, 2 February 2001.
([16]) Following the House of Lords decision in Page v. Smith (1996) AC 155, it is sufficient if any personal injury to a 'primary' victim is foreseeable.

Part of the rationale is that the since the 'employment of labor involves the risk of disability, by social policy the employer must defray its costs.' Expressed succinctly: 'The cost of the product should bear the blood of the workingman' (Franklin, 1979). When employees are harmed, there are costs; workers' compensation seeks to internalise those costs to the commercial activity that produces profits and harms employees.

Workers' compensation is financed by employers' contributions based on the hazards of particular kinds of employment ranging from quite hazardous jobs to office work. General tax revenues could fund such a system but this would likely disconnect compensation from current modest incentives for employers to provide a safer work environment. Moreover, since funding is largely employer based, it could and often does reflect a particular employer's safety record (Franklin, 1979). In addition, like tort law, workers' compensation laws in some jurisdictions permit discovery — but with a twist. Some jurisdictions only permit an impartial adjudicator to conduct discovery concerning injuries, while others allow the injured party to conduct discovery much like under tort law. While either option provides some of the same information benefits of tort, it slows the process, thus interfering to some extent with one of the strengths of workers' compensation: quick compensation and resolution of issues.

Initially workers' compensation only covered injuries resulting from the workplace, not diseases. Coverage has subsequently been extended, however, to include at least some diseases resulting from workplace exposures. Sometimes particular diseases resulting from particular working conditions are dealt with by separate legislation, e.g. black lung from coal mining. Many but not quite all workers are covered in the US. Domestic service employees, agricultural workers, casual employees, and possibly employees of small businesses tend to be excluded by statute (Franklin, 1979).

Injuries or diseases for which employees are authorised to receive compensation must fall within prescribed legislative categories. The injuries must be both explicitly authorised by the legislation or enabling regulations and attributable to a person's employment (Franklin, 1979). A back injury for which compensation is sought must be due to a workplace event, not weekend soccer.

Compensation typically consists of cash payments to an employee or his/her survivors, reflecting lost income, costs of medical care, and rehabilitative services. Lost income payments tend to be some percentage of the worker's weekly earnings at the time injuries were suffered, usually with a maximum payout, for example up to two thirds of the total earnings. This can vary depending upon marital status and whether the person has dependent children. Moreover, compensation is based on the generic kind of injury suffered, whether it was a temporary but partial disability, a temporary total disability, a permanent total disability, or death resulting from the workplace.

Payment amounts can be quite specific for a lost arm, leg, or particular finger, for example. When an employee dies as a result of a workplace injury, typically his or her survivors receive compensation based on the levels of earnings at the time and the number of his or her dependents. Medical and rehabilitative services provided by workers' compensation 'are generally considered to be the most effective single part of the system'. This is typically provided at once following an injury or disease (Franklin, 1979). Rehabilitative services can avoid other long-term costs that would otherwise result.

Finally, if the workers' compensation law in question does not cover a person or an injury or disease, remedies in tort law may be available. Ordinarily, workers' compensation is the exclusive remedy for workplace-caused diseases but if employees for some reason are not covered or poorly compensated for injuries, in some instances they may have recourse to the tort law.

In the US there are additional variations on workers' compensation. A federal version covers federal non-military employees. The Black-Lung Benefits Act 'provides compensation for [coal] miners suffering from 'black lung' (pneumoconiosis)'. Other laws provide compensation for employees injured by railroads, those working on ships, and those working for private maritime employers, but most of these provide compensation only if employers were negligent (Cornell University Law School, 2010). Some shortcomings of workers' compensation are considered at the end of the next section.

Analogues to workers compensation for a precautionary world

How well might generic strict liability analogues to workers' compensation laws function within a legal system oriented toward a precautionary approach to environmental health and environmental protection?

Imagine a generic compensation scheme that could compensate workers or citizens for injuries, diseases, dysfunctions or death as a result of an

environmental hazard, such as a chemical or other exposure. Imagine also that it provided compensation for environmental damage caused by products whose causal consequences were missed by prior review. How well would such a system function?

A well functioning system analogous to workers' compensation could have aspects consistent with a more precautionary approach to environmental and occupational health harms. It could provide compensation quickly to repair and rehabilitate people from injuries suffered. Once harms were identified, this would shorten their duration. But could analogues for environmental damages be devised? This more difficult issue would need to be addressed.

There is one major limitation. Workers' compensation laws function as well as they do because many injuries tend to be immediately cognisable and causally traceable to a source, e.g. a worker cuts off a finger or is in a car accident. Obvious and immediate traumatic injuries are easy to identify under workers' compensation programmes. Provisions for other injuries, such as diseases associated with workplace exposures, would need to be created as understanding of disease processes develops and as diseases can be causally attributed to exposures, e.g. how coke oven emissions can contribute to lung cancer (very easy) or bisphenol A can contribute to metabolic syndrome, breast cancer or adverse reproductive effects (extremely difficult). In a precautionary world creating categories of identifiable injuries, diseases or dysfunctions from many chemical exposures becomes more difficult when harms are not obvious, are not obviously traceable to a particular exposure or are not causally proximate to the time of exposure.

As a first step for comparatively new or poorly understood exposures to technologies, decision-makers could assess potential causes of harm from what is known about the technologies and any plausible adverse effects that might result. These could be used together with background information and analogies to the same adverse effect caused by other exposures or sources to create presumptive categories of adverse outcomes and appropriate compensation. For example, at present the evidence may or may not be sufficient to identify various forms of electromagnetic waves as contributors to brain cancer. However, there is surely considerable knowledge about the costs of treating different brain cancers and how much these forms of cancer disrupt people's lives so that if it turns out that cell phones do contribute to some forms of brain cancer, compensation tables could begin to be developed even before the causal evidence is fully sufficient to support a case for compensation.

In addition, decision-makers could 'learn as they go', and assess and evaluate kinds of diseases and dysfunction based on the causal properties of the substance as they are revealed over time. It would take some time to build up categories of injuries that would be more or less automatically compensable. For known hazardous but socially important chemical products whose toxicity was better understood, compensation tables could be developed somewhat quicker.

Another amendment might be a procedure for monitoring for any potential adverse health or environmental effects from risky but socially important products or activities, such as lead. This is highly toxic product with no known safe level of exposure but it is likely to have continued use in batteries (Wigle and Lanphear, 2005). Lead companies would need to continue monitoring the health status of their employees for known adverse effects of lead exposure. Neighbourhoods or communities downwind or downstream from lead battery factories or recycling plants would need to be monitored in order quickly to detect health or environmental effects from fugitive lead exposures for compensation and to expedite its delivery.

For environmental harms there would need to be categories of plausible or even remote harms for which there would be compensation based on liability without fault. There would also need to be monitoring programmes in place to identify long-tailed risks as early as possible so that harm could be minimised and its duration shortened. Such efforts could probably be expedited by experts giving careful thought to potential adverse effects, where these estimates would be made on the basis of existing information and analogies to similar outcomes caused by other sources. For instance, for a genetically modified weed killer new to the market, there might well be recent historical examples of other weed killers, genetically modified or not, that when released into the environment posed problems of killing beneficial plants from which decision-makers could learn. For genetically modified plants with in-built pesticides that are close relatives to wild types that could pose problems, decision-makers could learn from analogies.

Despite the appearance that workers' compensation is more efficient, faster and without many of the transaction costs of tort law, over time it appears that this system's apparent attractiveness has been reduced in practice. Compensation rarely appears to

be adequate, some employees engage in fraud, and companies resist workers' compensation provisions. The public perceives that system as substantially flawed at present. An additional worry for long-tailed risks would be whether companies that caused harms continued to exist long enough for the results of their activities to appear.

Analogues to the US Vaccine Injury Compensation System

The Vaccine Injury Compensation System (VICP), a hybrid of the regulatory and tort systems in the US, constitutes another model. Pharmaceutical manufacturers at one time argued that they could no longer manufacture vaccines because there was too little profit margin and even that could quickly disappear if the few people who suffered adverse reactions to vaccines were permitted to sue. Congress created the Vaccine Injury Compensation Program to encourage the production of needed vaccines by providing a streamlined procedure to compensate those who, in rare instances, experienced a vaccine-related injury. This was an alternative to traditional tort actions concerning injuries caused by vaccines and companies were immunised from suits by the legislation.

The Program has two main parts: compensation for so-called 'on table' injuries from vaccines, and compensation for 'off-table' injuries. On-table injuries are identifiable and have typical adverse effects from particular vaccinations. These receive fairly automatic compensation with minimal evidentiary showings.

Off-table injuries are those that might be causally attributable to a vaccine but the injury is atypical. People using this remedy may file a petition 'against the Department of Health and Human Services in the US Court of Federal Claims seeking compensation from the Vaccine Trust Fund'. They must specify who was injured, the vaccine that caused it, when and where it was given, the type of injury, when the first symptoms appeared and how long any adverse effects lasted (USHRSA, 2010).

For off-table injuries, tort law standards of proof apply, but the requirements on expert testimony set out in Daubert v. Merrell-Dow Pharmaceuticals (1993) do not because the magistrate hearing the case is both judge and juror. There is no need to screen a jury from experts; judges simply assess such testimony and give it appropriate weight. In addition, there are fewer formal procedures than in a typical tort case and the magistrates in this system appear to have a much more sophisticated grasp of scientific evidence than the general federal district judges that hear tort cases (Stevens v. the Secretary of Health and Human Services, 2001).

Successful petitioners may receive compensation for past and future non-reimbursable medical, custodial care, and rehabilitation costs, as well as up to USD 250 000 for pain and suffering, lost earnings and/or reasonable lawyer expenses. Death benefits of up to USD 250 000 plus reasonable legal fees are also permitted (USHRSA, 2010).

The Program is funded by an excise tax of USD 0.75 on each dose of vaccine (USHRSA, 2010). Thus, the costs of VICP seem likely to be paid by patients, their insurance companies or the government (in the case of those with government aid). During the 12 years of its existence it has provided 'a less adversarial, less expensive and less time-consuming system of recovery than the traditional tort system that governs medical malpractice, personal injury and product liability cases. More than 1 500 people have been paid in excess of USD 1.18 billion' since its inception. This averages to about USD 78 000 per plaintiff (US Department of Justice, 2010).

In principle, an analogue to the VICP appears to be a superior compensation system to torts and might function well in a legal system that emphasised the importance of precautionary policies. How might it work?

If a potentially hazardous product has been tested and subject to pre-market review (for example under Europe's Registration, Authorisation and Restriction of Chemicals (REACH) system) or is subject to post-market health regulations, neither might be sufficient to protect all those contaminated by the substance. Some will be more susceptible, some less so, because of life-stage, genetic heterogeneity, variation in detoxifying enzymes, age, pre-existing illnesses and so on. Some provisions need to be provided for citizens who are harmed because health standards failed to protect them (Cranor, 2008a).

For injuries that are typical of such exposures — analogous to 'on-table' injuries — there should be virtually automatic compensation. (The list of such injuries would obviously need to be developed and revised over time.) For injuries that were not typical but were suspected of being causally traceable to the toxic exposure subject to regulation, injured parties could make an argument that the compensation system should recognise such injuries with a standard of evidence similar to those employed in the VICP.

How well might such a system function? First, there would need to be a table of expected or not atypical injuries to people or damage to the environment from exposures in order to create the equivalent of 'on-table' injuries subject to compensation. This is a necessary element to expedite compensation. How difficult it might be to create such tables for more subtle diseases and dysfunctions is difficult to know but it should be addressed.

Second, there would need to be some showing that appropriate exposure had occurred that would support the connection between the technology and the adverse effects. Unlike vaccines where exposures are typically known with some degree of confidence, for environmental and even some workplace exposures, this critical element would likely be subject to numerous disputes.

Third, explicit provisions would be needed for long-tailed, subtle, adverse consequences of the technology, making it possible, with reduced procedural requirements, to argue that people or the environment had been damaged as a consequence. One might think of these as something like the off-table injuries if they were more atypical adverse effects.

A possible shortcoming of analogues to VICP is that tort law's preponderance of evidence standard is needed for off-table injuries. This attenuates the chances of compensation for those whose injuries that may have been caused by exposures — at least compared to the United Kingdom's Compensation Scheme for Radiation-Linked Diseases (discussed below).

September 11 Victim Compensation Fund

This fund was created by a separate law passed following the 11 September 2001 terrorist attack on New York city. Its aim was 'to provide compensation to any individual (or relatives of a deceased individual) who was physically injured or killed as a result of [the 11 September attacks].' Congress sought 'in part, to establish a mechanism that would provide financial security and assistance to the victims of the attacks without the uncertainties, delays and costs of traditional litigation' (Feinberg, 2004).

The legislation creates an administrative alternative to traditional tort litigation for the victims of the terrorist attacks. Injured parties were permitted to seek tort compensation instead but with substantial limitations. The law created a 'Special Master' with substantial powers to issue any 'procedural and substantive rules' and to determine eligibility under them. The Special Master had authority to determine the amount of compensation for harms suffered by those making the claims where this includes both economic and non-economic damages. Neither liability nor punitive damages could be considered. Congress authorised the funds necessary to pay compensation costs, but placed no aggregate limit on the total fund or on individual claimants (Feinberg, 2004).

The result was a hybrid system utilising some aspects of tort law but precluding liability and punitive damages. It authorised reduction of compensatory awards 'by payments that the claimant received from certain collateral sources'. Congress tried to create a comparatively quick and fair system for the victims. This was enforced by imposition of 'strict time limits' during which claims could be evaluated. Not everyone harmed by the attacks was eligible — only those 'individuals physically harmed or killed at the sites and in the immediate aftermath of the attacks.' Congress sought to ensure awards that were individualised between parties but not overly disparate between them. The details of these regulations and how they were implemented are described in the final report (Feinberg, 2004).

The Compensation Fund was created following a major tragedy and the enabling legislation passed in less than one week. There was no debate about the need or justification for compensation, which is likely to be quite different from analogous legislation that might cover environmental or environmental health harms. Moreover, there is a critical feature of this law that differs from traditional tort law. It was enacted and implemented in a manner similar to administrative or regulatory law: the Justice Department and Special Master had to implement regulations that would guide the award of compensation and considerations the Special Master had to take into account. The Master also had considerable discretion in deciding on individual amounts of compensation. There was provision for one to appeal these decisions, but appeals were considered within the same organisation that made the initial compensation decision instead of a separate appellate court. Once an appellate decision was issued, no further appeals were available. Thus, unlike the tort law or US administrative law, appeals were quite limited and were heard by lawyers within the structure created by the legislation (Feinberg, 2004).

This example does suggest that a compensation fund might be created under administrative procedures

rather than procedures more closely analogous to tort law. There could be rules issued for guiding an administrator or administrative agency in awarding damages and damage awards would be upheld on appeal as long as the administrative agency did not act to violate administrative procedures for adjudicating compensation under the rules.

In the US, an agency awarding compensation would probably be reviewed to determine whether it had 'substantial evidence' for its conclusion, assuming it had otherwise followed proper procedures. Thus, a reviewing court would consider whether, on the record established by the agency, it 'could reasonably make the finding'. Substantial evidence is 'such relevant evidence as a reasonable mind might accept as adequate to support a conclusion . . . [or provides] a substantial basis of fact from which the fact in issue can be reasonably inferred' (Davis, 1972). While this is somewhat vague, it conveys the idea that such decisions are reviewable, and acknowledges deference to the decisionmaker, but is not so strict as to force frequent second-guessing.

UK Compensation Scheme for Radiation-Linked Diseases

In 1965 the United Kingdom passed the Nuclear Installations Act to provide for civil liability for injuries from nuclear installations. This imposed strict or absolute liability for such injuries, rather than requiring proof of negligence. Despite this, subsequent litigation concerning such damages was complex, contentious and slow.

Consequently, this led to a voluntary Compensation Scheme for Radiation-Linked Diseases (CSRLD) in 1982. This was a joint agreement between British Nuclear Fuels Ltd (BNFL) and trade unions that worked within it. The aim was to create a quicker, more generous alternative to the normal litigation process, and reduce stressful and expensive litigation for complainants and expensive litigation for BNFL. Ultimately this was expanded to include other employers using radiation, and their unions. The Compensation Scheme initially permitted only compensation for mortality but later expanded to include morbidity. This agreement was possible because the causes of radiation-induced cancers were well understood as a result of past experience (CSRLD, 2010).

In order to make a claim under this programme, an employee must have worked for one of the companies that is a party to the agreement and have received a radiation dose during employment with one of the signatory companies. He or she must also be a member of a union that was party to the agreement, with some exceptions. The person must have been diagnosed with a disease that is typical of radiation exposure. Most cancers are considered eligible.

Compensation is determined by a person's radiation dose record from signatory employers, which is then used to assess the likelihood that a disease was caused by the exposure in question. Signatories have guidelines for determining the dose to which a person was exposed. The methodology to determine probabilities of causation and interpretation of uncertainties are generous toward claimants.

If a claimant is found to have radiation-induced cancer as a result of workplace exposure, the full value of a settlement is agreed by the parties and then discounted by the probability that it was the result of workplace exposure. Minimal compensation is awarded if the causation probability is 20 %, whereas in tort litigation the requirement for compensation would be at least 50 % (more likely than not).

If the odds of radiation-caused cancer are between 20 and 29.9 %, a quarter of the full value of a settlement is provided. If it is between 30 and 39.9 %, half is compensated, and from 40 to 49.9 %, 75 % of the full value is paid. If the probability of cancer is greater than 50 % then the full value of the disease is compensated. Most compensation that has been dispensed is for probabilities of causation below 50 %. One hundred and six people have received compensation for radiation-induced injuries, with payments totalling GBP 5.3 million or about GBP 50 000 per person on average.

Claimants have been much more likely to be successful than if their cases had been considered under tort law. They have received some compensation for their diseases based on the best information available, which was probably much quicker and more generous than civil litigation would have provided. The Scheme had therefore achieved its goals (CSRLD, 2010).

The United Kingdom also has a single-payer health system, the National Health Service (NHS), under which all citizens, including those suffering from illnesses caused by radiation, would receive essentially free health care for any diseases. Consequently, it would be difficult to compare compensation received under the CSRLD with compensation received in a country such as the US with myriad private health care providers and insurers.

In the United Kingdom, radiation-exposed employees would receive diagnosis and treatment for their diseases as quickly as the NHS provides it; this seems independent of the timeliness of compensation under the CSRLD. CSRLD compensation assists in setting right other matters beyond health care and rehabilitation for radiation-caused diseases. Clearly, countries with a single-payer system have quite important institutional resources that permit harm to be minimised and shortened as much as can be achieved through medical care and the rate at which patients are considered by the medical system.

Compensation under the CSRLD is possible because there is a substantial medical and exposure history with radiation. Well-designed, scientifically based compensation tables can be provided based on past injuries to earlier employees. Such a scheme could not be instituted quickly because creating the compensation tables depends so critically on a history of previous diseases. For new and subtle diseases, more likely to be typical of contemporary technological risks, this would be a limitation.

There appear to be modest incentives for companies to control exposures to radiation and reduce diseases and death as a result of this programme. If employees contract radiation-caused diseases, the company responsible must pay the required compensation, which is considered 'generous', and some packages are awarded based on probabilities well short of the preponderance of evidence. How successful this is likely to be in deterring dangerous exposure is difficult to judge. Will compensation packages in at least some cases be much less than the costs of preventing the diseases in the first place, especially when they involve substantial capital commitments? If so, the compensatory payouts by themselves would lack deterrence value. Of course, there could be other protective mechanisms, such as regulatory rules, inspections and so on.

New Zealand's no-fault compensation law

In 1972 New Zealand abolished almost all of its existing tort system and moved toward expanding a no-fault injury compensation scheme for compensating workers for personal injuries under the Accident Compensation Corporation (ACC). Initially covering workplace and automobile injuries, this was later expanded 'to cover virtually all accidental injuries and to confer very broad benefits on victims' (Schuck, 2008). Covered categories include motor vehicle accidents, work-related injuries both to employees and self-employed people, employees injured outside the workplace, medical treatment injuries, and coverage for those outside the workforce, such as children and the elderly.

Compensation is provided for injuries suffered, medical and rehabilitation costs associated with treating injuries, replacement of wages up to 80 % of average weekly earnings, impairment of earning capacity, loss of bodily function, possibly lump sum payments for permanent injuries, and benefits for surviving spouses and children, as well as funeral expenses. Injured people 'receive free hospital care and subsidized pharmaceuticals' (Bismark and Paterson, 2006). Compensation comes from different accounts corresponding to accident types and the category of victim involved. Peter Schuck observes that 'New Zealanders today generally regard their system … as a mainstay of their social policy' (Schuck, 2008). Others note that the 'ACC system is one of the simplest in the world for patients to navigate' (Bismark and Paterson, 2006).

Compensating all medical treatment injuries led to substantial costs and, consequently, for medical injuries subsequent legislation reduced 'the scope of covered injuries, shortened the time within which claims could be brought, and eliminated lump sum payments for pain and suffering' (Schuck, 2008). The programme reintroduced the notion of fault, similar to the US requirement of negligence for medical malpractice. In this New Zealand reverted to the previous standard of care that had been used in tort medical malpractice suits before instituting the ACC. There do not appear to be such restrictions for other 'accidents' in the workplace — from automobiles, and so on.

Illnesses not caused by accidents and wilful self-inflicted injuries are excluded from compensation, creating tensions within the system (Henderson, 1981). Injured parties who are not employed, such as children and the elderly, may not be similarly compensated, since they receive no earnings equivalent (Bismark and Paterson, 2006).

Aspects of the New Zealand system in large part seem consistent with a precautionary view of the world. It is relatively simple to navigate and claims are dealt with expeditiously, minimising the time before injuries are addressed. This in turn should shorten the duration of harm that must be endured. It appears that all accidents (with minor exceptions) are eligible for compensation.

A serious shortcoming appears to be the ineligibility of illnesses, at least with respect to the

medical compensation system. Moreover, the focus on 'accidents' might suggest that it is traceable to earlier views in which illnesses were seen as resulting from 'natural' processes, not induced by human activities. The result is that the system might underemphasise illnesses, dysfunctions or death traceable to toxic and other environmental exposures. In addition, the system appears to lack deterrents discouraging activities that lead to accidents (or illnesses).

Precautionary assurance bonds for environmental damage

Liability regimes for environmental damage are helpful but apply after the damage is done (EC, 2008, 2009 and 2010). A more precautionary approach to future environmental damage could involve the use of assurance bonds.

An assurance bonding system is an arrangement in which commercial entities whose activities might have adverse impacts on the environment must 'pay in advance for the costs they might inflict on society if they adopted the most harmful method of disposal, [it] reverses the usual presumption of 'innocence' over 'guilt' as applied to environmental damages' (Costanza and Perrings, 1990). A simple example is a refundable deposit on glass bottles. This encourages users to dispose of the bottles by returning them to a location where they would be recycled instead of their becoming litter, thus providing incentives for better disposal.

Because it is difficult or impossible to calculate the costs of future damage, it is unlikely that a private insurance market could encourage similar behaviour. There are therefore two alternatives: costs from future damage could be imposed on public agencies or privately injured parties when damage occurs, or they could be imposed on the party engaging in an activity that could have possible adverse future consequences.

Assurance bonds impose responsibility and costs on the entity undertaking the activity that might adversely affect health or the environment. A government body would estimate potential future costs of adverse environmental consequences and impose a fee for those on any party whose activities threatened environmental resources.

Under the scheme, each resource user would be required to post bonds, refundable at specified dates if the intertemporal external costs of the activity turned out to be less than those assessed by the environmental authority. The value of the bond at the date of posting would be a function of the environmental authority's [best] estimate of the costs of environmental repair or rehabilitation if the worst happened between the date of posting and the refund date. The value of the bond would be higher, the greater the estimate of the worst case costs (Costanza and Perrings, 1990**).**

The bond would be refundable in whole or part if the resource users could demonstrate lower damages than those assumed by the agency setting the bond. The burden of proof that the estimate of the agency was incorrect would lie with the user of the resource**.** The system should therefore provide a strong economic incentive to firms to research the future environmental costs of their activities, and so to improve their environmental performance. If the environmental authority's estimate of the worst case costs were revised downwards during the life of the bond it would be reduced; if revised upwards it would be increased. This feature of the scheme provides the incentive to resource users to research the future environmental effects of their activities (Costanza and Perrings, 1990).

Such bonds provide a means for addressing ignorance and uncertainty associated with possible future environmental hazards, as well as deterring undesirable behaviour. When businesses are required to post bonds, if harm from their activities occurs, there are resources that can assist in whole (the preferred alternative) or in part (less preferred) in compensating those whose property or person have been harmed and assist in repairing damage to the environment. The greater the upfront bond, the more likely adequate resources would be available to address adverse consequences. Of course, a bonding scheme would need to be supported by an appropriately quick and adequate compensation system similar to the best ones we have considered above.

Assurance bonds have a number of virtues. They provide incentives for private parties and government agencies to conduct research and improve estimates of adverse environmental impacts before the activities are instituted. They also internalise these calculations into the procedures of a commercial enterprise with nudging from environmental agencies. They help correct underinvestment in research on such adverse effects. The funding of environmental protection through the bonds would be proportionate to the size of the problem insofar as this could be determined. And the inducement for research would also be approximately proportional to the assessed social costs of permitting the activity to proceed in ignorance (Costanza and Perrings, 1990).

If companies cannot afford the upfront bonds, they would not be permitted to engage in the activity; in short, no bond, no market.

Importantly, bonds help protect against economically marginal firms whose activities might turn out to be especially environmentally damaging. If they are marginal, they would likely lack resources to address the problems after they occurred and simply go out of business or declare bankruptcy rather than provide compensation for damage caused. Bonds required for activities prior to instituting a potentially hazardous activity would provide funds when firms are optimistic about their activities to ensure that there will be resources to address problems when they arise, even if the firms are no longer in business (provided funding is held in trust). This resembles a common rationale for administrative regulation of risks rather than post-market injury suits to repair damage when risks materialise into harm (Cranor, 1993).

Assurance bonds promote a precautionary approach, placing approximate upfront costs on commercial activities insofar as these can be determined. They do not require testing or estimates of adverse effects of products or activities as does REACH, but they provide incentives for it. If in fact harm occurs, there is then a fund, hopefully adequate, to begin to repair, minimise and shorten damage.

Moreover, because bonds provide incentives to conduct research to discover future harms, they might assist in discovering long-tailed, less visible adverse consequences of technology earlier. They might provide some incentives for businesses to reveal risks earlier in order to increase funds that might be returned should harms be minimised. While there is no explicit deterrence in the form of punishments or penalties, the equivalent of some deterrence exists because firms have resources at stake, which they would lose if there were adverse consequences, but which would be refunded if there were not.

A possible downside is that assurance bonds might overly burden new technologies, possibly discouraging investment in new but potentially risky activities. This concern might be addressed by requiring upfront bonds commensurate with the extent of risks. For low probability, relatively contained risks when enterprises are small, lesser bonds could be required, but as commercial activities grow and the range of risks increases, bonds should probably be increased appropriate to potential costs of risks. The size of commercial activities would need to be monitored in order for the bond fund to keep pace with potential risks. Governmental agencies may or may not be up to the task of on-going monitoring. An illustration of how an assurance bond scheme could have been applied to the Deepwater Horizon disaster is provided in Panel 24.3.

24.2.3 Desirable features of compensation systems

Comparatively quick measures to identify diseases and environmental damage due to poorly understood technologies and quickly minimise and shorten them would promote precautionary approaches better than slower systems. There are tensions between the rationales of the different compensatory systems reviewed above. Different ones might be more appropriate for the varying circumstances and institutions of individual countries, e.g. the presence of universal health care or existing compensation systems like New Zealand's.

The best compensation systems appear to have nearly automatic provisions for many classes of injuries (ideally all). It may be difficult to provide tables for automatically compensable health injuries and illnesses, and for environmental damage from less well understood technologies, but decision-makers must do the best they can. This might be more difficult for subtle, long-tailed risks. Some of these problems would be eased in countries with single-payer, universal health care such as many countries in Europe have, and in New Zealand's no-fault compensation system for accidents, with extensions to diseases and the environment.

A compensation arrangement with some similarities to administrative law and some features of the September 11 Fund in the US might be desirable. In this an administrator would have considerable discretion to award compensation and it would likely be more efficient in quickly providing resources to repair damages suffered. There would, however, need to be some constraints on decision-maker discretion to ensure justice between applicants and to utilise funds efficiently.

The generous compensation system of the UK's Compensation Scheme for Radiation-Linked Diseases, with allowances for compensating for cancers with probabilities less than 50 % is notable. It could be difficult to duplicate, however, because it rests on a long, well understood history of radiation-caused diseases with prior victims. It is nevertheless worth considering.

Panel 24.3 Precautionary assurance bonds for potentially serious environmental risks

Robert Costanza has long advocated anticipatory assurance bonds on corporations as a means of internalising and helping to minimise future environmental costs from their large scale, potentially hazardous technologies (Costanza and Perrins, 1990). His argument is summarised below, based on lessons from the Deepwater Horizon oil spill.

The spill from the *Deepwater Horizon* offshore drilling rig in 2010 is causing enormous economic and ecological damage. The spill has directly and indirectly affected at least 20 categories of valuable ecosystem services in and around the Gulf of Mexico. The USD 2.5 billion per year Louisiana commercial fishery has been almost completely shut down. As the oil extends to popular Gulf Coast beaches, the loss of tourism revenue will also be enormous. In addition, the spill has damaged several important natural capital assets whose value in supporting human well-being is both huge and largely outside the market system. These non-marketed ecosystem services include climate regulation via the sequestration of carbon by coastal marshes and open water systems, hurricane protection by coastal wetlands, and cultural, recreational, and aesthetic values.

A recent study estimated the total value of these ecosystem services for the Mississippi River Delta to be in the range of USD 12–47 billion per year (Batker et al., 2010). Based on the flow of these services into the future, the value of the Delta as a natural asset was estimated to be in the range of USD 330 billion to USD 1.3 trillion, far more than the total market value of BP (USD 189 billion) before the spill. Unlike BP, ecosystem service values are outside the market. They continue to produce benefits unless an action like the spill damages them.

One major lesson is that our natural capital assets and other public goods are far too valuable to continue to put them at such high risk from private interests. We need better (not necessarily more) regulation and strong incentives to protect these assets against actions that put them at risk. Our current approach to dealing with the risk of private interests damaging public environmental assets is to assign liability to the private interests, but with the burden of proof on the public. The public must demonstrate damages after the fact, claim compensation, endure a lengthy judicial process, and finally hope to recover just reparations. In addition, the total liability is often limited, as with oil spill and nuclear accident cost. This gives private interests strong incentives to take large risks with public assets — far larger than they should from society's point of view.

The long-term solutions to these problems require fundamental changes to business-as-usual practices, including assessment and incorporation of the full value of public natural capital assets into both corporate and public accounting and decision-making, a reversal of the burden of proof from public to private interest, and a requirement of corporations and other private interests to internalise and monetise their risks to public goods.

One way to internalise and monetise these risks would be to require private interests to post an 'assurance bond' large enough to cover the worst-case damages. Portions of the bond (plus interest) would be returned if and when the private interests could demonstrate that the suspected worst-case damages had not occurred or would be less than was originally assessed. If damages did occur, portions of the bond would be used to rehabilitate or repair the environment and to compensate injured parties. The critical feature is that the risk to the public asset is apparent to the private interests in financial terms before the fact, not as a liability that may or may not be enforced after the damage occurs.

Imagine how this system might have worked had it been in place prior to the Deepwater Horizon incident. What actually occurred is pretty close to the 'worst-case' scenario that might have been envisioned before the fact. Our best guess of the potential damages would thus be in the range of USD 34–670 billion. Let's say that a scientific review panel, after assessing the risk in more detail, settled on an estimate of USD 50 billion. This immediately makes it very apparent to BP and others drilling in deep water in the Gulf of Mexico that they are engaged in a *very* risky business — several orders of magnitude riskier than the USD 50 million liability limit previously in force. What could they do? Either not drill at all or find ways to reduce the size of the risk and the bond. They might be able to do this very cost-effectively if they spent some money on risk-reduction procedures or technology, such as the acoustic blowout preventer costing a mere USD 500 000 which they failed to install on Deepwater Horizon. These measures might convince the scientific review panel to change its assessment of the

Panel 24.3 Precautionary assurance bonds for potentially serious environmental risks (cont.)

worst-case scenario and reduce the bond. There would be very strong economic incentives for BP to find creative ways to reduce the risks rather than ignoring the risks and cutting corners.

The *Deepwater Horizon* incident offers a strong lesson in risk management. Our entire society is taking far too many risks with public assets whose real value we are only now beginning to recognise. By shifting the financial burden of those risks onto the private interests who benefit from them, we can establish the right incentives, shift investment to less risky, more productive pursuits, and create a more sustainable and desirable future.

Source: Costanza et al., 2010.

Funding for some of the systems suggests useful features of a model. Workers' compensation and the Vaccine Injury Compensation Program in the US all institute a fee on the covered activities to create a monetary source from which compensation can be paid. This is likely to be attractive to government agencies facing tightened budgets or long-term budgetary concerns. Moreover, if contributions to a compensation fund are based to some extent on a company's safety record with regard to the activity, this may provide some modest deterrence feedback to the company to modify its safety practices toward the new technology. Workers' compensation funds do this explicitly; there is no 'deterrence surcharge' in the VICP and it is not clear that there is such a surcharge in the UK's radiation compensation programme.

Health care and rehabilitation services, likely to be part of some but not all health care systems do not exhaust compensatory needs. People's loss of earning capacity and long-term care, as well as compensation for families left poorly supported, must be addressed.

Assurance bonds or insurance if it is available in the markets, paid for upfront by companies whose technologies appear to pose health or environmental risks, provides important resources to help fund anticipatory research into risks and to provide compensation so that society does not have to pay for any future damage. When companies put up their own money, this provides incentives for better research on risks associated with their technologies and deters carelessness or recklessness in creating such risks.

24.3 Conclusion

Early warning scientists and others who identify potential impending harm have sometimes been discouraged in the past or actually lost positions or suffered various kinds of losses. However, they often bring forth useful and timely knowledge and therefore need to be encouraged and not harmed for their efforts. Good public policy suggests laws should discourage such actions in the first place and justice requires rectification if they are the subjects of retaliation. And if warnings are not heeded and damage results, or if damage results even when there were not warnings, it has often proved difficult in the past to achieve prompt and fair compensation for the victims.

This chapter has explored some ideas for reform, building on some current institutional models in the hope that this will raise awareness of these issues among the wider public and suggest plausible improvements in current law and practices.

References

Abel, R., 1988, 'Torts', in Kairys, D. (ed.), *The Politics of Law: A Progressive Critique*, Basic Books, New York, pp. 445–470.

Ad-hoc Industry Natural Resource Damage Group, 2010, *Survey of industrial companies insurance and other financial security instruments and remediation of environmental damages under the EU Environmental Liability Directive*, February 2010, Brussels.

Anderson v. Minneapolis, St. Paul & S. St. M.R.R. Co., 1920, 146 Minn. 432, 179 N.W. 45.

Batker, D., de la Torre, I., Costanza, R., Swedeen, P., Day, J. and Boumans, R, 2010, *Gaining Ground—Wetlands, Hurricanes and the Economy: The Value of Restoring the Mississippi River Delta*, Earth Economics Tacoma, WA.

Bismark, M. and Paterson, R., 2006, 'No-Fault compensation in New Zealand: harmonizing injury compensation, provider accountability, and patient safety', *Health Affairs*, (25/1) 278–283.

Berger, M., 1997, 'Eliminating General Causation: Notes Towards a New Theory of Justice and Toxic Torts, *Columbia Law Review*, (97) 2 117–2 152.

Boxill, B., 2011, 'Black Reparations' in: Zalta, E. N., (ed.), *The Stanford Encyclopedia of Philosophy* (Spring 2011 Edition).

Brodeur, D., 1985, *Outrageous misconduct: the asbestos industry on trial*, Pantheon, New York.

Cambridge Water Co. v. Eastern Counties Leather, 1994, 1 All ER 53 (H.L.)

CEA, 2007, *CEA white paper on insurability of environmental liability*, Confederation of European Insurers (http://www.insuranceeurope.eu/uploads/Modules/Publications/Mail%20-%20CEA%20White%20Paper%20on%20Insurability%20of%20Environmental%20Liability.pdf) accessed 30 May 2012.

CEA, 2008, *The Environmental Liability Directive — enhancing sustainable insurance solutions*, Confederation of European Insurers (http://www.insuranceeurope.eu/uploads/Modules/Publications/environmental-liability-report.pdf) accessed 30 May 2012.

CEA, 2009, *Navigating the Environmental Liability Directive — A practical guide for insurance underwriters and claims handlers*, Confederation of European Insurers (http://www.insuranceeurope.eu/uploads/Modules/Publications/1240585425_eld-best-practice-guide-update.pdf) accessed 30 May 2012.

Cornell University Law School, 2010, 'Workers' Compensation' (http://topics.law.cornell.edu/wex/workers_compensation) accessed 4 June 2010.

Cone, C., 2005, *Silent Snow*, Grove Press, New York.

Costanza, R. and Perrings, C., 1990, 'A Flexible Assurance Bonding System for Improved Environmental Management', *Ecological Economics*, (2) 57–75.

Costanza, R., Batker, D., Day, J., Feagin, R.A., Martinez, M.L. and Roman, J., 2010, 'The perfect spill: solutions for averting the next Deepwater Horizon', *Solutions*, June 2010 (http://www.thesolutionsjournal.com/node/629).

Cranor, C.F., 1993, *Regulating toxic substances: a philosophy of science and the law*, Oxford University Press, New York.

Cranor, C.F., 2006, *Toxic torts: Science, Law, and the Possibility of Justice*, Cambridge University Press.

Cranor, C.F., 2007, 'A framework of assessing scientific arguments: gaps, relevance and integrated evidence', *Journal of Law and Policy*, 15:7–57.

Cranor, C.F., 2008a, '(Almost) equal protection for genetically susceptible subpopulations: a hybrid regulatory-compensation proposal', in: Marchant, G. (ed.), *Genomics and Environmental Policy*, Johns Hopkins University Press, Baltimore, MD, pp. 267–289.

Cranor, C., 2008b, 'The dual legacy of *Daubert v. Merrell-Dow Pharmaceutical, Inc.*: trading junk science for insidious science', in: Wagner, W. and Steinzor, R. (eds), *Rescuing science from politics: regulation and the distortion of scientific research*, Cambridge University Press, New York, pp. 130–142.

Cranor, C.F., 2011, *Legally Poisoned: How the Law Puts Us at Risk from Toxicants*, Harvard University Press, Cambridge, MA.

CSRLD, 2010, 'The Compensation Scheme for Radiation Linked Diseases, scheme history' (http://www.csrld.org.uk/html/scheme_history.php) accessed 30 May 2012.

Daubert v. Merrell Dow Pharmaceuticals, 509 U.S. 579 (1993).

Davis, K. C., 1972, *Administrative Law Text*, West Publishing Co., St. Paul, Minnesota.

EBTP, 2009, 'European Business Test Panel consultations 2009' (http://ec.europa.eu/yourvoice/ebtp/consultations/2009_en.htm) accessed 30 May 2012.

EC, 2008, *Financial security in Environmental Liability Directive —* final *report*, August 2008, European Commission, Brussels (http://ec.europa.eu/environment/legal/liability/pdf/eld_report.pdf) accessed 30 May 2012.

EC, 2009, *Study on the implementation and effectiveness of the Environmental Liability Directive (ELD) and related financial security issues — final report*, November 2009, European Commission, Brussels (http://ec.europa.eu/environment/legal/liability/pdf/

ELD%20Study%20November%202009.pdf) accessed 30 May 2012.

EC, 2010, *Report from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions under Article 14(2) of Directive 2004/35/CE on the environmental liability with regard to the prevention and remedying of environmental damage*, European Commission, Brussels, 12.10.2010 COM(2010) 581 final.

EEA, 2001, *Late lessons from early warnings: the precautionary principle 1896–2000*, Environmental issue report No 22, European Environment Agency.

EU, 1992, Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, OJ L 206, 22.7.1992, p. 7.

EU, 2006, Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, December 18, 2006, no. 1907/2006 (UK) (hereafter, REACH).

EU, 2009, Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version), OJ L 20/7, 26.1.2010.

Feinberg, K., 2004, *Final Report of the Special Master of the September 11 Victim Compensation Fund* (http://www.justice.gov/final_report.pdf) accessed 31 May 2012.

FERMA, 2010, *Survey on Environmental Liability Directive Report*, Federation of European Risk Management Associations.

Franklin, M.A., 1979. *Injuries and remedies: cases and materials on tort law and alternatives*, The Foundation Press, Inc, Mineola, NY.

Friedman, F., 1985, *History of American Law*, Touchstone, New York.

General Electric v. Joiner, 1997, 522 U.S. 136.

Gillette C.P. and Krier, J. E., 1999, 'Risk, courts and agencies', *University of Pennsylvania Law Review*, vol. 38, pp. 1077–1209.

Guth, J., 2009, 'Law for the ecological age', *Vermont Journal of Environmental*, vol. 9, pp. 431–512 (www.vjel.org/journal/pdf/VJEL10068.pdf) accessed 29 May 2012.

HLR, 2011, 'Corporate law — securities regulation — Congress expands incentives for whistleblowers to report suspected violations to the SEC', *Harvard Law Review* Vol. 124, pp. 1 829–1 836 (http://www.harvardlawreview.org/media/pdf/vol124_recentlegislation05152011.pdf) accessed 30 May 2012.

Henderson, J. A., Jr., 1981, 'Review: rhe New Zealand Accident Compensation Reform', *The University of Chicago Law Review*, (48) 781–801.

Honore, T., 1995, 'The morality of tort law — questions and answers', in: *The Philosophical Foundations of Tort Law*, Clarendon Press, Oxford.

House of Commons, 2009, *Whistleblowing: 'The Public Interest Disclosure Act of 1998*, House of Commons Library

Kaplan, E., 2001, 'The international emergency of legal protections for whistleblowers', *The Journal of Public Inquiry*, Fall/Winter 2001, pp. 37–-45.

Kumho Tire v. Firestone, 1999, 526 U.S. 137.

Leigh, W. J. and Wakeford, R., 2001. 'Radiation litigation and the nuclear industry — the experience in the united kingdom', *Health Physics, (*81) 646–664.

Lyndon, M. L. 'the toxicity of low-dose chemical exposures: a status report and a proposal,' book review of legally poisoned: how the law puts us at risk from toxicants, *Jurimeterics: Journal of Law, Science and Technology*, (52) 457–500.

Markowitz, G. and Rosner, D., 2002, *Deceit and denial: the deadly politics of industrial pollution*, University of California Press, Berkeley.

McIntyre, O., 2004, 'Liability for asbestos-related illness: redefining the rules on 'toxic torts', *Judicial Studies Institute Journal, (*180).

Mercer, J., 2010, *In Praise of Dissent* , Ode , 1 August, http://odewire.com/50372/in-praise-of-dissent.html

Merrell Dow Pharmaceuticals Inc. v. Havner, 1997, 953 S.W.2d 706 at 718 (Supreme Court of Texas).

Miller, C., 2002, 'Judicial approaches to contested causation: Fairchild v. Glenhaven Funeral Services in context', 1 *Law, Probability and Risk*, 119–139.

Milward v. Acuity Specialty Products, Inc., 2011, 639 F.3d 11 (First Circuit Court of Appeals).

Morgan, A., 2002, 'Inference, principle and the proof of causation', *NLJ*, 12 July 2002.

National Research Council, 2002, *Environmental effects of transgenic plants: the scope and adequacy of regulation*, National Academy Press, Washington, D.C.

Prosser, W. and Keeton, P., 1984, *On the law of torts*, 5th ed., West Publishing Co., St. Paul, Minn.

Priest, G.L., 2003, 'The Problematic Structure of the September 11th Victim Compensation Fund', *DePaul Law Review*, (53) 527–545.

Saks, M. J., 2000, 'Do we really know anything about the behavior of the tort litigation system – and why not?, *Pennsylvania Law Review*, (140) 1 147–1 289.

Schuck, P. H., 2008, 'Tort reform kiwi-style', *Yale Law and Policy Review*, (27) 187–203.

Sindell v. Abbott Laboratories, 1980. 26 Cal. 3d 588, 607 P. 2d 924.

Stevens v. Secretary of Health and Human Services, 2001, WL 387418 (Fed. CI).

Summers v. Tice, 1948, 33 Cal. 2d 80,109 P.2d 1.

Sunstein, C., 2005, Why Societies need Dissent, Harvard University Press.

UCS, 2012, *Heads they win, tails we lose — How corporations corrupt science at the nation's expense*, Scientific Integrity Program of the Union of Concerned Scientists.

US Department of Justice, 'Vaccine Injury Compensation Program' (http://www.justice.gov/civil/common/vicp.html) accessed 30 May 2012.

USHRSA, 2010, 'US Department of Health and Human Services, Health Resources and Services Administration, National Vaccine Injury Compensation Program', (http://www.hrsa.gov/vaccinecompensation/index.html) accessed 30 May 2012.

Wigle, D. T. and Lanphear, B. P., 2005, 'Human health risks from low-level environmental exposures: no apparent safety thresholds', *PLoS Medicine*, (2) 1–3.

Woolley, D., Pugh-Smith, J., Langham, R and Upton, W. (eds), 2000, *Environmental Law*, Oxford University Press.

WTO, 2008, *'United States-Continued Suspension of Obligations in the EC-Hormones Dispute', Appellate Body, p 27, para 65,* World Trade Organization, WT/DS320/AB/R, 16 October.

25 Why did business not react with precaution to early warnings?

Marc Le Menestrel and Julian Rode

In the past, companies have frequently neglected early warning signals about potential hazards for human health or the environment associated with their products or operations. This chapter reviews and analyses relevant interdisciplinary literature and prominent case studies — in particular those documented in both volumes of *Late lessons from early warnings* — and identifies main factors responsible for the disregard of early warning signals.

The chapter shows how economic motives often drive non-precautionary business decisions. In virtually all reviewed cases it was perceived to be profitable for industries to continue using potentially harmful products or operations. However, decisions are also influenced by a complex mix of epistemological, regulatory, cultural and psychological aspects. For instance, characteristics of the research environment and the regulatory context can provide business actors with opportunities to enter into 'political actions' to deny or even suppress early warning signals. Also, business decision-makers face psychological barriers to awareness and acceptance of the conflicts of values and interests entailed by early warning signals. Cultural business context may further contribute to the denial of conflicts of values.

The chapter concludes with a set of reflections on how to support more precautionary business decision making. A prominent policy response to the conflicting interests of business and society is introducing regulations that attempt to steer business rationality towards internalising external effects. Innovative solutions such as assurance bonding should be considered.

There is a need to better understand and expose why business actors do not respond voluntarily to early warning signals with precautionary actions. Blaming business, in particular with hindsight, tends to be common reaction that may not always be constructive. It often misses the complex or even contradictory set of motives and drivers that business actors face.

Public institutions could support progressive business by analysing and publically disclosing the dilemmas and temptations entailed by early warning signals, for example for different industries and for the specific societal and regulatory context of decisions. Rigorous and explicit exposition of the dilemmas will create further incentives for responsible actors to share and communicate their precautionary responses.

An additional reflection centres on the role of political actions of business actors, in particular those actions aimed at suppressing early warning signals. Regulatory efforts that make the political actions of business more transparent can help to sustain a sound balance of power, thereby maintaining our ability to benefit from early warning signals and reducing the likelihood of health and environmental hazards.

25.1 Introduction

Late lessons from early warnings (EEA, 2001) describes a number of prominent cases in which early warning signals about potential hazards from the use of commercial products or operations have been neglected over long periods of time, eventually with grave consequences for human health and the environment. While the volume derives lessons which focus primarily on improving decision-making by regulatory agencies, it becomes also very clear that decisions to act with precaution — or the failure to do so — often involved business actors. Private companies have been the main drivers of innovative activity and, notwithstanding the benefits they have generated for society, their business practices and products have in many instances also caused considerable harm. In essence, EEA (2001) shows that business decisions played a major role when things went wrong.

So why did companies not act with precaution when early warning signals were available? In this paper, we review case studies from EEA (2001) as well as some additional 'early warnings' cases which appear in this volume. We look for patterns in these past experiences and study relevant interdisciplinary academic literature with the aim to analyse and better understand the situation of companies that are confronted with early warnings. We identify several potential impediments for business decision-makers to act in a precautionary manner, which we summarise in three 'lessons about business'. We conclude with some reflections on how to support more precautionary business decision-making in the face of early warning.

There is no doubt that many business actors recognise their responsibility to strive for economic benefits, in line with a wider regard for human welfare and with respect for the natural environment (see WBCSD, 2010). This analysis should be useful for decision-makers to be aware and better understand the challenges and potential pitfalls of business behaviours when dealing with early warnings. For policy makers as well as the general public, the analysis should foster a more integrative and differentiated judgement of the role of (different) types of business actions towards society.

25.2 Impediments for companies to respond to early warnings in a precautionary manner

25.2.1 Economic rationality

The standard economic paradigm that underlies typical present day business decisions takes root in the times of classical industrial society (Shrivastava, 1995). Private corporations in a market economy are regarded as systems of production with the purpose of profit maximisation. In such a worldview, economic value created by business actors is understood primarily as financial returns to owners, typically the shareholders. Though a variety of novel approaches have been brought forward (e.g. Kelly, 2001, 2012), this paradigm is the main driver behind management decisions. It is embedded in decision tools across corporate units, and remains the core element of management education. Since half a century, it has been to a large extent shared and supported by mainstream ideology and the public perception of the role of business within a free market society (Friedman, 1970; Karnani, 2010).

The idea of profit maximising firms embraces a rationality according to which ethical values are reasons to act if and only if they contribute to the expected economic benefits for the business actor (Le Menestrel, 2002). In particular, nature and society at large are external to the business environment, and potential societal and environmental costs are not to be taken into account in business decisions unless they imply potential costs for the business actor. Accordingly, the internal risk evaluation that is part of the standard cost-benefit analysis toolbox is typically limited to minimising financial business risk, i.e. the comparison of expected revenue or profit figures (Sommerfeld, 2010). External risks to human health or the environment may enter the calculations, but only insofar as they indirectly pose a business risk via legal liabilities, regulatory restrictions or reputation risks for the company.

Economic rationality is thus remote from a proactive precautionary response to early warning signals. Virtually all reviewed cases have in common that early warnings about harmful effects were available, but that the prospect of short-term profit generated strong economic incentives for companies to continue with their practices. The most efficient fishing methods (EEA, 2001, Ch. 2), the sales and use of cheap and effective substances such as benzene (EEA, 2001, Ch. 4), lead in petrol (Chapter 3), asbestos (EEA, 2001, Ch. 5), insecticides (Maxim and van der Sluijs, 2007 and Chapter 16), or growth hormones for meat production (EEA, 2001, Ch. 14) are only some of many examples. Moreover, competitive market forces can further increase the economic pressure for using potentially hazardous product or for gaining a monopoly position from early introduction of innovative products or methods (Gollier and Treich, 2003; Maxim and van der

Sluijs, 2007). Voluntary preventive measures and costly scientific research that may confirm the harm or the involved risks are usually expected to be detrimental to financial performance.

Reputation
Public concerns or 'conscious consumer' preferences for safe products and operations have the potential to induce economic incentives for socially or environmentally responsible business behaviour (Banerjee et al, 2003; Rode et al., 2008). A company that is economically rational will not sell a product that, for reasons of public concern or lack of consumer trust, may not be profitable or give rise to consumer boycotts. The eventual termination of the use of antimicrobials (EEA, 2001, Ch. 9) and of growth hormones (EEA, 2001, Ch. 14) for meat production in Europe was driven to some extent by growing public concern about potential health risks. Such public concern can be a powerful force, no matter whether it is driven by the available scientific evidence or, in some cases, unrelated to evidence, or even overrating the dangers (Sunstein, 2003). In many cases, however, the public lacks knowledge about early warnings, underrates the risks (see also Section 25.2.4 on psychological factors), or does not feel affected. Under these circumstances, public concern about specific uncertain hazards of a particular product or industry is generally absent or weak. Consequently, reputation does not provide a sufficient economic incentive for precautionary behaviour.

Moreover, economically rational companies can decide to influence public opinion in their favour when this appears cheaper than reducing or terminating the potentially harmful practice. If companies themselves hold information about potential harm of their products or operations, they can choose not to disclose it. Voluntarily disclosing early warning signals about a potential hazard creates the risk that consumers refrain from buying the product, and consumers seem to reward transparency and honest disclosure of negative information only under very limited conditions (Aktar and Le Menestrel, 2010). When negative information is generated outside the company and becomes public, we describe below that companies have in the past employed a variety of measures to influence public opinion in order to prevent or at least weaken reputation risks.

Economic interest in preventing harm
In some instances, specific industries stand to lose from potential hazards and have an economic interest in precautionary termination of the potentially harmful activities. For example, when inshore cod fishers in Newfoundland suffered from falling catches due to unsustainable off-shore fishing practices (EEA, 2001, Ch. 2), they reacted with protests and the commissioning of a report, which gained media attention and eventually lead to an official reappraisal of the situation on depleted fish stocks. The Arcachon oyster industry feared the harmful effects of TBT as antifouling biocides for boats and strongly supported the implementation of restrictions on the use of TBT (EEA, 2001, Ch. 13). Beekeepers suspected early on a toxic effect of the insecticide Gaucho on bee populations and fought hard for the recognition of the evidence (Maxim and van der Sluijs, 2007 and Chapter 16). These cases, however, seem to be a minority compared to those where industries have direct and strong economic motives against taking precautionary measures.

25.2.2 Uncertainty in science and the research environment

Scientific uncertainty
The research community is expected to provide the necessary scientific evidence for determining whether early warnings of hazards are credible and substantial enough to justify precautionary measures. However, the prevalence of scientific uncertainty about hazards can weaken acceptance of such evidence and act as an impediment to precautionary responses to early warning signals. Here it is important to consider, however, that the uncertainties that companies face today are increasingly characterised by indeterminacy and even ignorance (Stirling, 2003). Typical examples are the effects of industrial operations and substances on (marine) ecosystems (EEA, 2001, Ch. 2) and the uncertainties regarding environmental or health effects of mobile phones (Chapter 20), GMOs (Chapter 18) or nano-technologies (Chapter 21). It seems difficult for people to cognitively deal with and to act upon such strong uncertainty (Weber, 2006 — see also Section 25.2.4 on psychological aspects below) and to comprehend the complexity of natural systems (Sivakumar, 2008; Kysar, 2009). Moreover, it becomes problematic to apply the standard risk analysis tools that are based on cost-benefit analysis and require knowledge of the set of possible outcomes and estimated probabilities of their occurrence, which are not always available (Ashford, 2005). It remains a challenge for social science, and in particular for business research, to develop appropriate concepts and operational tools that help companies deal with this type of uncertainty (e.g. Kunsch et al., 2009).

Secondly, it is often not recognised — and not communicated sufficiently to the general public — that even when scientific evidence with probabilistic data exists, uncertainty is an intrinsic and essential characteristic of science. There is no scientific justification of a 'sufficient level of confidence' or for the appropriateness of a confidence interval of 99 % or 95 % (Crawford-Brown et al., 2004; Ashford, 2005), and it is an ethical or political issue rather than a scientific one to determine an 'acceptable level of risk' for a 'reasonable fraction of the population' (Crawford-Brown et al., 2004). Moreover, in light of different scientific methods (e.g. based on direct evidence, correlations, model predictions), levels of data quality (e.g. with respect to statistical properties, reliability, relevance or level of scrutiny), and different lines of evidential reasoning (e.g. with respect to conceptual clarity, logical deduction, methodological rigor) the 'weight of evidence' from scientific results is almost always open to subjective judgment and interpretation (Crawford-Brown et al., 2004; Rauschmayer et al., 2009).

Interpreting and 'manufacturing' uncertainty

The uncertain and sometimes ambiguous nature of scientific evidence seems to stand in a stark contrast to the perceptions and idealistic expectations of science by the general public (Ravetz, 2005; van den Hove, 2007) and to its preference for complete certainty for justifying actions, in particular when the actions involve concrete costs (Dana, 2003). This allows industry lobbyists to oppose or prolong precautionary measures by 'manufacturing uncertainty' and generating doubt on the state of scientific evidence. Examples abound where corporate public relations efforts have exploited the subjectivity in judgment and interpretation of particular results, and used rhetorical tricks to emphasise the remaining uncertainty and the need for further research. Rampton and Stauber (2001) give an early account of such processes, while Oreskes and Conway (2010) provide a historical perspective of this controversial interface between science and business. One may also look at Sismondo (2008) for an example in the pharmaceutical industry.

According to Maxim and van der Sluijs, (2007 and Chapter 16), Bayer seems to have repeatedly used selective knowledge and 'semantic slips' to blur the evidence of a toxic effect of Gaucho on bee populations. In the case of benzene, manufacturers hired consultants to downplay the importance of scientific evidence and to introduce irresolvable arguments about dose-response analysis, which delayed governmental regulation (EEA, 2001, Ch. 4). Monsanto in the 1960s launched a public defense of PCBs, arguing that scientific evidence was not clear, and that it would take extensive research, on a worldwide basis, to confirm or deny the initial scientific conclusions (EEA, 2001, Ch. 6; Francis, 1998). Shell in 1967 circumstantiated its denial of a causal relationship between leaking chemicals and effects on wildlife and human health in the Great Lakes area by publishing a report saying that fish killed due to chemical contamination had not been verified by recent studies (EEA, 2001, Ch. 12).

Brush Wellmann in the 1980s hired PR specialists to create a more favourable public opinion and to reassure customers of the safety of beryllium, for instance by claiming that any reports of disease at less exposure than the current limit were scientifically unsound. In the late 1990s, when it was beyond doubt that the established beryllium exposure limit was not effective in protecting workers, Brush Wellmann initiated more research and convened a conference that propagated the need for further research before any new limit could be set (see the analysis at the end of Chapter 6). The millions of pages of previously secret internal tobacco industry documents, made public in the Minnesota trial, revealed the extent to which the effects of nicotine were known and intentionally blurred for consumers by creating doubt about the health risk (Hurt and Robertson, 1998). Similarly, in order to 'keep the debate alive', the tobacco industry financed the creation of new research institutions to carry out research on the effects of second hand smoking (Hong and Bero, 2002 and Chapter 7).

In the early days of the debate about climate change, Exxon was publicly contesting the science, based on its complexity and associated uncertainties. While presenting itself as 'a science and technology-based company', its strategy of preventing political action on climate change was chiefly implemented through efforts in publicly denying the existence of the problem that they had privately identified (van den Hove et al., 2002). In essence, by emphasising the lack of scientific certainty companies can contribute effectively to a 'paralysis by analysis' that prevents precautionary measures in response to early warning signals (EEA, 2001).

Corporate influence on scientific research

When industry and research are interacting closely, for instance in medicine (Sismondo, 2008), companies can also directly influence scientific results. They do not even have to manipulate results or engage in other forms of misconduct, which may happen in some cases (Francis, 1998), but they can effectively bias research results in their own interest by inducing so-called (pro-industry) design

and publication biases. It is common that the main indicator of scientific confidence of a harmful effect is the number of published studies that provide evidence for the effect vs. the number of studies that do not find one. This overall impression of sheer number of scientific results, however, can easily be altered through the selection of which scientific studies to actually carry out (Lexchin and O'Donovan, 2010). In particular since companies typically have significant financial means, they can strive to misrepresent the weight of results in their favour by sponsoring those scientific studies and methods which can be expected to produce favourable results.

As prominently done by the tobacco industry (Grüning et al., 2006), companies can further enhance this bias by organising symposia and publishing their proceedings. Symposia proceedings are typically not peer-reviewed, but still cited as published results. Another example where these strategies were applied is research on the health effects of lead in petrol. As reported in Chapter 3, the relevant studies were conducted and funded exclusively by the Ethyl Corporation and General Motors for over 40 years, and General Motors controlled the publication of results and imposed tight reporting constraints on the regulating US Bureau of Mines. In this case, it is even said that critical independent scientists had their funding withdrawn and their jobs and lives threatened. In the Gaucho debate in the 1990s, Bayer relied almost exclusively on their own research to argue against evidence of toxicity (Maxim and van der Sluijs, 2007 and Chapter 16). In the case of beryllium (Chapter 6), Brush Wellmann financed new publications within the beryllium health and safety literature under the names of well-known academics.

Unfortunately, these cases weaken the credibility of privately sponsored research and create a difficulty for companies that have a genuine and honest interest in objective and unbiased research about the risks of their products or operations.

25.2.3 *Gaps and loopholes in the regulatory framework*

A perfectly operating regulatory system would employ appropriate mechanisms to assure that companies only take the risks that are deemed acceptable by society at large. Commonly used regulatory mechanisms are legal constraints that limit or prohibit certain activities, laws that prescribe safety standards, or liability and tax systems that align the economic interests of the company with the interests of society (Pigou, 1912). The Precautionary Principle is widely recognised as guidance to 'err on the side of caution' and to opt for preventive regulatory measures when an activity is believed to threaten human health or the environment, even if there is no scientifically established evidence (Tickner and Raffensberger, 1998). Within a perfect regulatory system, it may be argued that the sole responsibility of a company is 'to increase its profits so long as it stays within the rules of the game' (Friedman, 1970). Many of the reviewed cases revealed, however, that the regulation which actually constrained corporate decision-making in the face of early warning signals, were far from such an ideal regulatory system. The following paragraphs highlight some key gaps and loopholes of the regulatory framework.

Incomplete information for regulation

First, regulators often do not have the complete information that would be necessary for imposing all appropriate constraints. On the one hand, this is of course due to the high degree of uncertainty or ignorance inherent in the activities, such as currently for nanotechnology or for GMOs. In addition, however, regulatory measures such as legal bans, safety standards or contingency plans often rely on information that is generated within the companies whose products or activities have to be assessed (EEA, 2001). For instance, companies may be the ones to first recognise early warning signals, as exemplified in the famous article of Bill Joy, the co-founder and Chief Scientist Officer of Sun Microsystem, alerting the public about the risks of genetically modified organisms, robotics and nanotechnology (Joy, 2000). Even in the presence of information disclosure rules, it is frequently up to the companies to reveal such 'private information' to the regulatory agencies. Not revealing important information can hence delay or distort regulatory action.

Regulation rarely induces full internalisation of externalities

Apart from their *ex post* role of ensuring justice, liability regimes are meant to provide *ex ante* the incentive for companies to internalise potential harm to society or the environment in their business decisions, to make sure that companies have the financial means for compensation, and to motivate complete risk assessment as well as precautionary measures (Boyd, 1997). In accordance with the 'polluter pays' principle, financial responsibility rules would take the form of strict liability to pay for potential harm. Alternatively, 'assurance bonding' can require companies to deposit a premium that

would cover the costs of potential damage before undertaking the dangerous activity (Kysar, 2009).

In many past cases, however, limited or even complete absence of liability have undermined the polluter pays principle and left companies without economic incentives to internalise external risks. Then, external costs from corporate action are typically borne by society at large. In the case of fisheries (EEA, 2001, Ch. 2) there was no corporate liability in place to account for externalities of overfishing and the costs to restore stock is to be paid by governments of the respective adjacent states. Similarly, the majority of external costs from MTBE in petrol (treatment of contaminated water, alternative water supply, health costs etc.) were borne by society (EEA, 2001, Ch. 11). For asbestos in the United Kingdom, it is argued that the market price of asbestos was so low since it did not internalise the external costs, which remained with families, health service, insurance carriers and building owners (EEA, 2001, Ch. 5). Even though laws on prevention, compensation, and sanctions existed as early as in the 1930s, they were simply not appropriately implemented.

There are other important aspects that determine the effectiveness of liability regimes in steering corporate conduct. For instance, the evidentiary strength to determine when liability comes into effect may be more or less strict, ranging from the need of 'clear and convincing evidence' vs. 'more probable than not' vs. 'preponderance of evidence', or the requirement of a 'substantial cause or factor' vs. 'contributing factor'. In addition, it is crucial whether the legal burden of persuasion is with those who suffer the harm or whether it is the responsibility of the industry to prove that no harm was done (Ashford, 2005). Clearly, a company facing a legal situation in which the victim has to provide convincing evidence that the corporate activity was a substantial cause for the suffered harm can expect fewer costs than in other situations, e.g. in which the burden of proof of no harm lies on the company.

It has also been noted that insolvency risk can further undermine full cost internalisation by companies, especially when harm would only occur in the far future (Boyd, 1997). For instance, Manville Corporation filed for bankruptcy in 1982 as a means of dealing with asbestos pollution claims (EEA, 2001, Ch. 5), when it was far too late to act with precaution towards asbestos.

Conflicting mandates of regulatory agencies

The implementation of a regulatory framework that adequately constrains companies for protecting society from potential hazards requires that the responsible governmental agencies have a clear mandate to do so. Governmental agencies sometimes have conflicting mandates. Before establishment of the US EPA, for instance, the US Department of Agriculture was responsible for environmental regulation in the debate on chemical contamination of the Great Lakes. As a supporter of the economic interests of the agro-industry, it tended to align itself with the pesticide manufacturers and the farmers, demanding proof of causal relationship before 'massive' approbations and expenditures of public and private funds on remedial works' (EEA, 2001, Ch. 12). In a similar fashion, the US Department of Fisheries and Oceans (DFO), which was responsible for reporting the scientific evidence on overfishing, is said to have followed the interests of the fishery sector (EEA, 2001, Ch. 2). The DFO is accused of having presented biased results, referring to remaining uncertainties, and of arguing against 'pseudo-science' and bad faith of early warnings.

Conflicting mandates of regulatory agencies are reported in further instances. In the case of the 'mad-cow disease', the responsible British Ministry of Agriculture, Fisheries and Food (MAFF) was expected simultaneously to promote the economic interests of farmers and the food industry whilst also protecting public health from food-borne hazards (EEA, 2001, Ch. 15). In the debate on the toxic effects of Gaucho, the French Ministry of Agriculture was responsible for the contradictory demands of intensive agriculture and beekeepers and at the same time for the management of risks issuing from the agricultural sector's activities (Maxim and van der Sluijs, 2007, and Chapter 16). The US Department of Energy (DOE) was responsible both for the cheap production of nuclear weapons and the protection of workers through appropriate beryllium exposure limit (Chapter 6).

Corporate influence on regulation

Regulators have in the past not always judged and decided objectively and independently with respect to corporate interests. In several cases, regulatory agencies and committees included experts with a conflict of interest, who could shape policy recommendations by interpreting scientific evidence in the interests of the industry. Again, the tobacco documents have revealed the extent to which industry is able to subvert public institutions. In a report about the strategies to undermine tobacco control activities of the World Health Organization, authors write that 'evidence from tobacco industry documents reveals that tobacco companies have operated for many years with the deliberate

purpose of subverting the efforts of the World Health Organization (WHO) to control tobacco use. The attempted subversion has been elaborate, well financed, sophisticated, and usually invisible' (Zelltner, 2000).

In the case of benzene (EEA, 2001, Ch. 4), the American Conference of Governmental Industrial Hygienists (ACGIH) repeatedly recommended benzene limits higher than those in line with scientific evidence on benzene poisoning. Scientists employed by various corporations participated in the Threshold Limit Value Committee that made exposure recommendations (Castleman and Ziem, 1988). In the early phase of using lead in petrol in the 1920s (see Chapter 3), public health specialists acted as paid consultants to the Ethyl Corporation while at the same time advising the US Government's Bureau of Mines, providing assurances of 'complete safety' for public health. In the pharmaceutical domain, conflicts of interest seem pervasive. Reviewing three European drug regulatory agencies, Lexchin and O'Donavan (2010) find evidence of widespread potential conflict of interests among scientific experts.

Last, companies can also influence regulation indirectly through the above mentioned influence on public perception of the involved risks. In an increasingly demand driven economy, public trust, consumer perceptions or NGOs can have a considerable influence on the politics and decisions of regulatory agencies (Aerni, 2004; Carter, 2002).

25.2.4 Psychological factors

There is ample evidence from the behavioural sciences indicating that people's capacity for proper recognition and evaluation of early warnings is limited. This section outlines prominent findings and assesses their role for business decisions and the perceptions of the general public.

Bounded rationality

A large body of psychological and 'behavioural economics' research is dedicated to the 'bounded rationality' of risk perception and decision-making under uncertainty, (Kahneman and Tversky, 1982). Psychological theories of judgment and decision-making provide a number of explanations for human failure to adequately process risks and probabilistic information. Note that the manifestation of potential hazards may be either described as low-probability events (e.g. a nuclear catastrophe), or, when the scientific evidence of an adverse effect is scarce, the likelihood of the effect will be formulated in terms of a low probability (e.g. the increase of cancer rates caused by exposure to a chemical substance). While low-probability events can be overestimated when they are vivid in people's mind (Kahneman, 2011), it has been shown that awareness of risks is more effectively communicated by engaging in direct experience and the associated emotions, rather than abstract statistical descriptions (Weber, 2006). Also, concrete losses or events have a much higher impact on people's beliefs than information about uncertain, abstract ones (Dana, 2003).

This focus on direct experiences as basis for decisions, however, leads human cognition to struggle with an appropriate consideration of low-probability risks as indicated by early warning signals. When early warnings signals occur, people have typically not directly experienced the hazards themselves. In that case, people tend to neglect the likelihood of rare events (Hertwig and Erev, 2009). As Kahneman (2011) emphasises, 'when it comes to rare probabilities, our mind is not designed to get it quite right. For the residents of a planet that may be exposed to events no one has yet experienced, this is not good news.' The psychological hurdles for a proper recognition and evaluation of early warnings apply to business decision-makers and the general public alike (Boyd, 1997). Note that in exceptional cases, this psychological disposition can trigger an opposite effect, namely when a low-probability event does indeed occur. Then, people may even — at least temporarily — overrate the probability of occurrence (Sunstein, 2003), and increased public concern may lead to faster regulatory measures. This may have been the case for the German decision to phase out nuclear energy after the Fukushima accident in 2011. In most situations, however, human risk perception seems to impede precautionary corporate action as well as public pressure for responding to early warnings with precaution.

A related phenomenon is the so-called 'pensioner's party fallacy', according to which people tend to overrate the fact that some people live long in spite of exposure to harmful substances and are hence still present at pensioners' parties — as opposed to their deceased colleagues — and this presence is perceived as evidence against the existence of harm (EEA, 2001). Here, people neglect the fact that their personal experience with formerly exposed colleagues is biased towards meeting the survivors. For instance, this effect is likely to play a role also for the perception of risks from smoking.

Another well documented characteristic of risk perception is that immediate losses or harm have

a larger bearing on people's beliefs than losses or harm in the future (Dana, 2003; Weber 2006). Economic models capture this systematic bias in preferences over time by using discount factors for present value calculation. Recent 'behavioural economics' approaches even use hyperbolic discounting to represent the seemingly exponential diminishing of value over time. This systematic bias works against precautionary measures since those measures typically involve direct costs in the present in order to avoid uncertain costs from harm in the — often far away — future. One may argue that people should decide freely on their 'time preferences' and that any type of paternalism on how to trade off present versus future consequences is inappropriate. Nevertheless, uncertain future hazards also involve consequences for future generations and discounting such consequences based on the time preferences only of the present generation may be questionable from an ethical point of view (O'Neill et al., 2008). There is currently a heated debate about an appropriate discounting of the effects of climate change and of biodiversity loss (Stern, 2006; Weitzman, 2007; Spash, 2007; TEEB, 2009).

Other findings on the limits to taking into account information about risks are noteworthy. For instance, the 'finite-pool-of-worries' hypothesis reflects that the degree of concern for a certain issue depends on the presence of other, perhaps more direct worries, such as the financial crisis, job security etc. (Weber, 2006). For most people, uncertain future hazards may not be high enough on the agenda to invoke any action. The 'single action bias' reflects the tendency not to take further action after one initial step, which leads to suboptimal behaviour when a portfolio of actions or a constant change in behaviour would be appropriate (Weber, 2006). Moreover, there is evidence for cultural differences in how health and safety risks affects decision-making (Biana and Keller, 1999). Last, even though we have not found psychological studies on the phenomenon, several reviewed cases reported that companies exploited people's tendency to interpret 'no evidence of harm' as 'evidence of no harm' (Chapter 3; Chapter 6; Zelltner, 2000).

Bounded ethicality

Apart from 'bounded rationality' in risk perception, there are psychological findings revealing 'ethical blindness' (Palazzo et al., 2012), 'ethical biases' (Banaji et al., 2003) or 'bounded ethicality' (Gino et al., 2008). A prominent and widely studied phenomenon is the 'self-serving bias', which refers to people's general tendency to interpret ambiguous situation in their self-interest (Babcock and Loewenstein, 1997). For decisions where self-interest conflicts with ethics, this implies that people engage in self-deception that helps them reinterpret or disguise that acting in their self-interest violates ethical principles. Such phenomena can be largely unconscious and psychologists tend to relate them to the reduction of a 'cognitive dissonance' (Festinger, 1957) that stems from conflicting goals such as making profit and acting ethical.

Self-deception may be enabled through different mechanisms, including language euphemisms and 'slippery-slope' decisions, where a series of small infractions of ethical standards can lead to a journey towards immoral conduct (Tenbrusel and Messik, 2004). In addition, people tend to hide from relevant knowledge on ethical attributes of decisions (Ehrich and Irwin, 2005) and to neglect those arguments or types of reasoning that may reveal them as responsible for immoral action (Rode and Le Menestrel, 2011). The self-serving bias seems of high relevance when business decision-makers face uncertain early warnings signals but precautionary measures are not in the economic interest of the company (Gollier and Treich, 2003). Strong uncertainty may not only be inherently difficult to integrate into risk assessment, but it may also serve as a welcome 'excuse' and justification about why the profitable action may not be so unethical after all.

Other research has shown that people tend to engage in self-deception also when evaluating potentially harmful behaviour of others, in particular that they overlook unethical behaviour of others that may harm them when that behaviour is not clear, immediate and direct, and when it has not yet resulted in a bad outcome (Gino et al., 2008). With respect to our analysis, such a tendency may further explain the public lack of awareness of inappropriate corporate responses to early warnings, and hence the public's reluctance to react with potentially supportive actions in their role as consumers, voters or engaged citizens.

For the case of asbestos, Sells (1994) provides testimony of the relevance of self-deception and denial as critical factors for why business actors fail to act with precaution in the face of early warning signals. He cites one of the presidents of Manville Corporation saying that 'the blunder that cost thousands of lives and destroyed an industry was a management blunder, and the blunder was denial. …Manville managers at every level were unwilling or unable to believe in the long-term consequences of these known hazards. They denied, or at least failed to acknowledge, the depth and persistence of management accountability' (Sells, 1994). It is as

if the combination of economic interests, scientific uncertainty, and psychological factors concur to trap business executives in an organisational culture where the danger is minimised and alternative business solutions unattainable: 'If an organisation's culture encourages denial, problems get buried. Corporate cultures are built by successful people, good men and women who are often pillars of their communities as well as business leaders. The executives at Manville were good people too, and nevertheless they fostered a culture of self-deception and denial' (Sells, 1994).

Evidence from the same company, however, also shows that such cultural factors can be reversed. The tragedy of asbestos and the eventual bankruptcy acted for Manville Corporation as a lesson for the company to stop its culture of denial and changed its approach towards products stewardship. In 1986, shortly after learning that its fiberglass products could be related to an increase in cancer rate, the company's leadership took precautionary action with regards to its operations and voluntary re-labeled these products as possibly carcinogenic despite the reluctance of their lawyers. The company benefited from this proactive strategy thanks to a successful indemnification and marketing strategy, proving that what may be perceived as a conflict of interest could well lead to a successful alignment of business and social values. It took then nearly five years to realise that the excess detected in respiratory cancer in fiberglass manufacturing workers were not sufficiently significant to justify such a warning label (Sells, 1994; Paine and Gant, 2009).

25.3 Lessons and reflections about business and early warnings

We now provide a set of lessons and reflections that summarise our findings and whose consideration may promote more precautionary business decision-making.

Lesson 1: early warning signals often entail conflict of values for business actors, who expect to be in their economic interest not to respond with precautionary 'business actions'

The cases we have studied here illustrate that early warning signals often raise conflicts between short term economic gains for business actors on the one hand and long term human health and environmental values on the other. Given that health and environment are regarded as issues pertaining to society at large or at least to multiple societal actors or groups, these conflicts of values are often conflicts of interest between business actors and public interest.

The reviewed cases illustrate how business actors tended to give priority to their short-term economic interest and did not respond to early warnings. This behaviour is in line with the standard economic and management paradigm, which regards maximising profits as the main objective of companies, as long as this is done respecting the relevant regulatory frameworks. In other words, when early warning signals entailed potential conflicts between profit and other societal values, economic interests pushed business to dismiss those business actions that would respond with precaution, such as modifying or terminating potentially hazardous products or operations.

Lesson 2: characteristics of the research environment and the regulatory context can provide business actors with opportunities to enter into 'political actions' to undermine early warning signals

When companies respond to early warning signals by giving priority to their business interest at the expense of public interest, they have a further incentive to suppress, contradict or downplay these early warning signals, both to maintain favourable public opinion and to avoid regulatory constraints. Many of the reviewed cases were characterised by a regulatory and societal context that allowed companies to effectively pressure science, lobby for favourable regulation and influence public opinion against the recognition and acceptance of early warning signals. In some cases, like tobacco, such actions contributed to discrediting national and international institutions and NGOs, weakening their ability to produce or relay early warnings signals. Because these actions go beyond strictly speaking 'business actions' but rather influence the societal context of business, they can be seen as 'political actions' and illustrate a political role of business actors (Scherrer and Palazzo, 2010). It seems therefore important to distinguish these types of actions from 'business actions', such as decisions to continue or not with a potentially hazardous product or operation. 'Political actions' are not aimed at maximising profits within the political and regulatory contexts but rather aim at influencing these political and regulatory contexts in the pursuit of profits.

Lesson 3: psychological and cultural factors contribute to neglecting early warning signals

Business decision-makers face psychological barriers to awareness and acceptance of the conflicts of values and of interest entailed by early warning

signals. Human risk perception and time preferences are biased towards underrating uncertain hazards, and there is a tendency to avoid the cognitive and emotional dissonances generated by the presence of value conflicts. In particular when own interests are at stake, it is well documented that people tend to reveal self-serving biases in their perception of the situation. Hence, when business actors have an economic interest in producing or using potentially hazardous substances, they are tempted to justify their behaviour by dismissing early warning signals and the conflicts of values they entail.

The cultural business context further contributes to the denial of conflicts of values entailed by early warning signals. Typically, the idea that the main objective of business is to maximise profit and the belief that this is the most appropriate way for business to serve society provide a powerful justification for dismissing the relevance of these value conflicts for business actors and to increase self-perception of responsibility. As in the asbestos example, organisational cultures can also explain the difficulty in facing the conflicts of values and of interest entailed by early warning signals.

Reflections about business and early warning signals

A prominent policy response to conflicting interests between business and society are regulatory measures that attempt to steer business rationality towards internalisation of external effects. We would agree that for uncertain hazards, proposals for legal, fiscal, and financial regulatory mechanisms still have a large potential to further align business interests with interests of society. Innovative solutions such as assurance bonding should be considered (Kysar, 2009). Yet, our article has outlined that precautionary business operations face further barriers that are of epistemological, psychological, political and cultural nature. Given the variety and complexity of these barriers, it seems unrealistic to believe that complete alignment of business interests with interests of society at large will always be feasible. At least in the short term, or until business actors indeed face the ideal societal and regulatory context, business decision-makers will face difficult situations with value conflicts. In our opinion, the possibility to discuss these conflicts of values rationally and openly is an absolute necessity to mature our responses towards them.

In particular, and notwithstanding the necessity to strengthen the accountability of business actors, we believe there is a need to better understand and expose the rationale for business actors not to respond voluntarily to early warning signals with precautionary actions. Blaming business, in particular with hindsight, tends to be a rather typical reaction that may not always be constructive. It often misses the complex or even contradictory set of motives and drivers that business actors are facing. When companies give priority to their business interest at the expense of precautionary actions, it is not necessarily because they willingly act against the interests of society or to harm the environment. Some business actors may well acknowledge the need to sacrifice some business interest, but may consider in good faith that the early warning signals are not strong enough to justify precautionary measures. Others may be unaware of the full extent of their conflicting interests and of their self-serving biases, for instance because of a cultural or an organisational context that is trapping them in a short-sighted economic approach.

We thus believe that a crucial first step towards any solution is awareness and acceptance of the dilemmas business actors are facing, and of the various temptations for business to act in a way that is harmful to society. Here, we can imagine that public institutions could support progressive business by analysing and publically disclosing the dilemmas and temptations entailed by early warning signals, e.g. for different industries and for the specific societal and regulatory context of decisions. This includes disclosure of the conflicts between making profit and causing potential societal harm, but also the psychological temptations to hide from such value conflicts, the temptations to use gaps and loopholes of regulation or to influence the regulators, as well as the temptations to influence the scientific evidence. Rather than prescribing specific precautionary business actions, such institutions could then promote more open, transparent, and stakeholder-inclusive participatory decision frameworks that recognise the reality and the difficulty of the complex trade-offs (Stirling, 2008).

Rigorous and explicit exposition of the dilemmas will create further incentives for responsible actors to share and communicate their precautionary responses. Clear and factual descriptions of these difficult situations, if possible devoid of judgemental considerations, may contribute to reducing unconscious denials, force business organisations to openly discuss the factors driving their decision-making (see Tenbrusel and Messik, 2004), and promote more transparency, proactive attitudes and innovative responses to difficult business decisions. Because they would make explicit the conflict of values, such institutional approaches

would more realistically complement initiatives based on the idealised principle that being socially responsible is economically profitable, typical of Corporate Social Responsibility (Porter and Kramer, 2011).

An additional reflection lies more specifically on the role of political actions of business actors, in particular those actions aimed at suppressing early warning signals. Even though they could be regarded as a natural tendency to justify and protect one's own interest, such political actions have the potential to disrupt an honest debate and to prevent the development of an appropriate context within which business actions lead to positive consequences for society. The fact that some business actors spend sophisticated efforts to hide or keep secret their political actions can be seen as a signal that their behaviour is of bad faith and would not be socially acceptable. Regulatory efforts that make more transparent the political actions of business can help to sustain a sound balance of power, thereby maintaining our ability to benefit from early warning signals and reducing the likelihood of health and environmental hazards.

References

Aerni, P., 2004, 'Risk, regulation and innovation: The case of aquaculture and transgenic fish', *Aquatic Sciences,* (66) 327–341.

Aktar, I., Le Menestrel, M., 2010, *Voluntary Disclosure of Negative Information May Enhance Consumers' Trust*, Miméo.

Ashford, N., 2005, 'Implementing the precautionary principle: incorporating science, technology, fairness and accountability in environmental, health and safety decisions', *International Journal of Risk Assessment and Management,* (5/2–4) 112–124.

Babcock, L., Loewenstein, G., 1997. 'Explaining bargaining impasse: the role of self-serving biases', *Journal of Economic Perspectives,* (11/(1) 109–126.

Banaji, M.R., Bazerman, M.H. and Chugh, D., 2003, 'How (Un)ethical Are You?', *Harvard Business Review* 81, no. 12.

Banerjee, S., Iyer, E., Kashyap, R., 2003, 'Corporate environmentalism: antecedents and influence of industry type', *Journal of Marketing,* (67) 106–122.

Bian, W., Keller, L., 1999, 'Chinese and Americans Agree on What Is Fair, but Disagree on What Is Best in Societal Decisions Affecting Health and Safety Risks', *Risk Analysis,* (19/3) 439–452.

Boyd, J., 1997,''Green Money' in the Bank: Firm Responses to Environmental Financial Responsibility Rules', *Managerial and Decision Economics,* (18) 491–506.

Carter, S.M., 2002, *Mongoven, Biscoe and Duchin: destroying tobacco control activism from the inside*, Tobacco Control, 11 Issue 2.

Castleman, B., Ziem, G., 1988, 'Corporate influence on threshold limit values', *American Journal of Industrial Medicine,* (13) 531–559.

Crawford-Brown, D., Pauwely, J., Smith, K., 2004, 'Environmental Risk, Precaution, and Scientific Rationality in the Context of WTO/NAFTA Trade Rules', *Risk Analysis,* (24/2) 461–469.

Dana, D., 2003, 'A Behavioral Economics Defense of the Precautionary Principle', *Northwestern University Law Review,* (97/3) 1 315–1 346.

Ehrich, K., Irwin, J., 2005, 'Willful Ignorance in the Request for Product Information', *Journal of Marketing Research,* (42/3) 266–277.

EEA, 2001, *Late lessons from early warnings: the precautionary principle 1896–2000*, Environmental issue report No 22, European Environment Agency.

Festinger, L., 1957, *A Theory of Cognitive Dissonance*, Stanford University Press.

Francis, E., 1994, 'Conspiracy of silence, The story of how three corporate giants — Monsanto, GE and Westinghouse — covered their toxic trail', *Sierra Magazine*.

Friedman, M., 1970, 'The Social Responsibility of Business Is to Increase Its Profits', *The New York Times Magazine*, 13 September 1970.

Gino, F., Moore, D., Bazerman, M., 2008, *See No Evil: When We Overlook Other People's Unethical Behavior*, Harvard Business School Working Paper 08-045.

Gollier, C., Treich, N., 2003, 'Decision-Making Under Scientific Uncertainty: The Economics of the Precautionary Principle', *Journal of Risk and Uncertainty,* (27/1) 77–103.

Grüning, T., Gilmore, A., McKee, M., 2006, 'Tobacco Industry Influence on Science and Scientists in

Germany', *American Journal of Public Health*, (96/1) 20–32.

Hertwig, R., Erev, I., 2009, 'The description-experience gap in risky choice', *Trends in Cognitive Sciences,* (13/12) 517–523.

Hong, M.K. and Bero, L.A., 2002, 'How the tobacco industry responded to an influential study of the health effects of secondhand smoke', *British Medical Journal*, (325/7377) 1 413–1 416.

Hurt, R., Robertson, C., 1998, 'Prying open the door to the tobacco industry's secrets about nicotine: The Minnesota Trial', *Journal of the American Medical Association,* (280/13) 1 173–1 181.

Joy, B., 2000, 'Why the future doesn't need us', *Wired*, 8.04, April issue.

Kahneman, D., Tversky, A. (eds.)., 1982, *Judgments under uncertainty: Heuristics and biases*, Cambridge University Press.

Kahneman, D., 2011, *Thinking, fast and slow*, Penguin, London.

Karnani, A., 2010, 'The Case Against Corporate Social Responsibility', *The Wall Street Journal*, 23 August 2010.

Kelly, M., 2001, *The divine right of capital: dethroning the corporate aristocracy*, Berrett-Khoeler Publishers.

Kelly, M., 2012, *Owning our future: The emerging ownership revolution*, Berrett-Khoeler Publishers.

Kunsch, P., Kavathatzopoulos I., Rauschmayer, F., 2009, 'Modelling complex ethical decision problems with operations research', *Omega-International Journal of Management Science,* (37/6) 1 100–1 108.

Kysar, D., 2010, 'Ecologic: Nanotechnology, Environmental Assurance Bonding, and Symmetric Humility', *UCLA Journal of Environmental Law & Policy,* (28/1).

Le Menestrel, M., 2002, 'Economic Rationality and Ethical Behavior. Ethical Business between Venality and Sacrifice', *Business Ethics: A European Review*, (11/2) 157–166.

Lexchin, J., O'Donovan, O., 2010, 'Prohibiting or 'managing' conflicts of interest? A review of policies and procedures in three European drug regulation agencies', *Social Science & Medicine,* (70) 643–647.

Maxim, L., van der Sluijs, J., 2007, 'Uncertainty: Cause or effect of stakeholders' debates? Analysis of a case study: the risk for honeybees of the insecticide Gaucho', *Science of the Total Environment,* (376) 1–17.

Monique E., Muggli, M., Richard D. Hurt, M. Douglas, D., Blanke, J., O'Neill, J., Holland, A., Light, A., 2008, *Environmental Values, Routledge*, London.

Oreskes, N., Conway, E., 2010, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, Bloomsbury Press.

Paine, L, Gant, S., 2009, *Manville Corporation Fiberglass Group*, Harvard Business School Cases 394–114,115,116,117,118.

Palazzo, G., Krings, F. and Hoffrage, U., 2012, 'Ethical Blindness', *Journal of Business Ethics, (*109/3) 323–338.

Pigou, A., 1912, *Wealth and Welfare,* Macmillan.

Porter, M., and Kramer, M. R., 2011, 'Creating Shared Value', *Harvard Business Review*, January Issue.

Rampton, S., Stauber, J., 2001, *Trust us, we're experts! How industry manipulates science and gambles with your future*, Penguin Putnam.

Ravetz, J. 2004. The post-normal science of precaution, *Futures,* (36) 347–357

Rauschmayer, F., Kavathatzopoulos, I., Kunsch, P., Le Menestrel, M., 2009, 'Why good practice of OR is not enough — Ethical challenges for the OR practitioner', *Omega,* (37/6) 1 089–1 099.

Rode, J., Le Menestrel, M., 2011, 'The influence of decision power on distributive fairness', *Journal of Economic Behavior and Organization,* (79) 246–255.

Rode, J., Hogarth, R., Le Menestrel, M., 2008, 'Ethical differentiation and market behavior: An experimental approach', *Journal of Economic Behavior and Organization,* (66) 265–280.

Sells, B., 1994, 'What Asbestos Taught Me About Managing Risk', *Harvard Business Review*, (72/2) 76–90.

Shrivastava, P., 1995, 'Ecocentric Management for a Risk Society', *Academy of Management Review,* (20/1) 118–137.

Sismondo, S., 2008, 'How pharmaceutical industry funding affects trial outcomes: Causal structures and responses', *Social Science & Medicine,* (66) 1 909–1 914.

Sivakumar, B., 2008, 'Undermining the science or undermining Nature?', *Hydrological Processes, (*22) 893–897.

Sommerfeld, H., 2010, *Integration des Risikomanagements in die Unternehmensführung — ein Changeprozess der Unternehmenskultur*, mimeo.

Spash, C., 2007, 'The economics of climate change à la Stern: Novel and nuanced or rhetorically restricted?', *Ecological Economics,* (63) 706–713.

Stirling, A., 2008, '"Opening Up" and "Closing Down" — Power, Participation, and Pluralism in the Social Appraisal of Technology', *Science, Technology and Human Values,* (33) 262–294.

Stern, N., 2006, *Stern Review on the Economics of Climate Change*, UK Government Economic Service, London.

Stirling A., 2003, *Risk, uncertainty and precaution: some instrumental implications from the social science*. In: Berkhout F, Leach M, Scoones I, editors. Negotiating environmental change: new perspectives from social science. University of Sussex: Eward Elgar, p. 33–76.

Sunstein, C., 2003, *Beyond the Precautionary Principle*, University of Chicago Public Law and Legal Theory Working Paper 38.

TEEB, 2009, *The Economics of Ecosystems and Biodiversity for National and International Policy Makers — Summary: Responding to the Value of Nature*.

Tenbrunsel, A., Messik, D., 2004, 'Ethical Fading: The Role of Self-Deception in Unethical Behavior', *Social Justice Research,* (17/2) 223–236.

Tickner, J., Raffensperger, C., 1998, 'The Precautionary Principle: A Framework for Sustainable Business Decision-Making', *Environmental Policy,* (5/4) 75–82.

Van den Hove, S., 2007, 'A rationale for science-policy interfaces', *Futures,* (39/7) 807–826

Van den Hove, S., Le Menestrel, M., de Bettignies, H.C., 2002, 'The oil industry and climate change: strategies and ethical dilemmas', *Climate Policy, (*2) 3–18.

WBCSD, 2010, *Vision 2050: The new agenda for business, World Business Council for Sustainable Development*.

Weber, E., 2006, 'Experience-based and description-based perceptions of long-term risk: Why global warming does not scare us (yet)', *Climatic Change,* (77) 103–120.

Weitzman, M., 2007, 'A Review of the Stern Review on the Economics of Climate Change', *Journal of Economic Literature,* (45) 703–724.

Zelltner, D.A., Martiny, A., Randera, F., 2000, *Tobacco companies strategies to undermine tobacco control activities at the World Health Organization*, Report of the Committee of Experts on Tobacco Industry Documents.