Costs of Inaction on Environmental Policy Challenges: Summary Report

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FOREWORD

When they met in April 2004, OECD Environment Ministers drew attention to the need for more analysis of the "costs of inaction" (COI) on key environmental challenges. Ministers also asked the OECD to work on this theme, and to report back at their next meeting. This report is part of the response to that request.

A high-level meeting of the OECD Environment Policy Committee was held (April 2005), to launch discussion on this topic. Since then, the OECD effort has concentrated on preparing final reports to respond to the mandate given by Environment Ministers in 2004. This report provides a summary for policy-makers on the costs of inaction in selected environmental policy areas. The report is not comprehensive – it covers neither all environmental problems nor all dimensions of those environmental problems it does address. The aim of the report is merely to offer some introductory perspectives on the topic; to provide some initial views based on the current literature; and to suggest some of the problems likely to be encountered in moving further in this (highly complex) area.

The report was drafted by Nick Johnstone, Ivan Hascic, and Tom Jones of the OECD Environment Directorate, working under the guidance of the OECD Environment Policy Committee and its Working Party on National Environmental Policies. It has also been materially improved by comments received along the way from delegates in OECD capitals and from other members of the Secretariat.

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COSTS OF INACTION ON ENVIRONMENTAL POLICY CHALLENGES: SUMMARY REPORT [ENV/EPOC(2007)16/FINAL]

Executive summary

- Estimating the "costs of inaction" on key environmental challenges is important because it allows policy-makers to better understand the nature and scope of these challenges, making it easier to decide when (and how) to intervene with policy. This is particularly important in the environmental field, because so many of the impacts of inaction are not reflected in markets.

- Defining and measuring the cost of inaction is complex – partly because of the environmental and economic uncertainties involved; but partly because of difficulties in establishing both the baseline and the boundaries for these estimates. For example, some of the costs of inaction will be incurred locally (and immediately), while others will fall on citizens in other countries (and perhaps in the distant future). Similarly some costs will be reflected in very tangible form (e.g. expenditures on health services), while others will be more intangible (e.g. "pain and suffering").

- This report summarises available evidence on the costs of inaction in four key areas of environmental policy:

  - air and water pollution effects on human health;
  - climate change;
  - environment-related industrial hazards and natural disasters; and
  - natural resource management.

- Despite the measurement difficulties, the existing literature suggests very strongly that the costs of policy inaction in selected environmental areas can be considerable -- in some cases, representing a significant "drag" on OECD economies. Although OECD governments have, for many years, developed policies to address these environmental challenges, much work remains to be done. In particular, work should be intensified to reduce some of the uncertainties involved in defining and measuring the marginal costs of *inaction*, so that eventual comparisons with the marginal costs of *action* can be as robust as possible.

1. Introduction

When they met in April 2004, OECD Environment Ministers drew attention to the need for more analysis of the "costs of inaction" on key environmental challenges. Ministers also asked the OECD to work on this theme, and to report back at their next meeting. This report is part of the response to that request. It begins by discussing a few key methodological and definitional issues. This is followed by a selective review of the empirical literature in the areas of air and water pollution, climate change, environment-related hazards and disasters, and natural resource management.[1]

[1] While clearly of continuing policy concern, the loss of biodiversity is not addressed explicitly in this report. A key reason is that a complementary study on this topic is being prepared by the European Commission (see http://ecas2004.lcp.be/cmdscripts/getdoc.asp?id=1235.htm#Costofpolicyinaction). On the other hand, some of the topics selected for examination in this report also have implications for biodiversity management (*e.g.* groundwater and fisheries management; climate change).

The report makes no attempt to be comprehensive – it covers neither all environmental problems nor all dimensions of those environmental problems it does address. Its aim is merely to offer a few introductory perspectives on the topic of "costs of inaction" (based on the existing literature); and to suggest some of the main problems likely to be encountered in exploring further this (highly complex) field.

It is important to be clear at the outset about what is meant by both "cost" and "inaction". OECD countries have already made significant strides in addressing many of the environmental concerns discussed in this report. While the continued implementation of existing policies can hardly be characterised as "inaction", adopting such a perspective is likely to be more pragmatic than "assuming away" the existing policy framework.

With respect to "costs", both market and non-market impacts are important, and are therefore considered within much of the literature reviewed for this report. This includes direct financial costs (*e.g.* expenditures on remediation and restoration), indirect costs reflected in other markets (*e.g.* real estate, labour markets), and indirect costs that are not reflected in markets at all (*e.g.* non-use values such as "existence values").

The literature reviewed for this report suggests that the economic costs of failing to introduce environmental policies, or of introducing policies that are not sufficiently ambitious or timely (which can be considered to comprise some form of "inaction"), can be considerable, and are already directly affecting national economies in a variety of ways. For example:

- *Air pollution* can lead to reduced agricultural yields, degradation of physical capital, and broader impacts on ecosystem health. The costs of not introducing the EC's "Thematic Strategy on Air Pollution" are estimated to represent about 0.35-1.0% of EU-25 GDP in 2020 (CEC, 2005). Although some of the tangible health costs of pollution (lost productivity, health service costs, *etc.*) may be more visible, economic studies suggest that more intangible costs, such as "pain and suffering", are very significant as well.
- In non-OECD countries, the economic impacts of inaction with respect to *water pollution* may be even greater. According to the WHO (Prüss-Üstün *et al.,* 2004), 1.7 million deaths and 4.4% of the burden of disease (BoD)[2] are attributable to unsafe water supply, sanitation and hygiene (WSH). Ninety per cent of these deaths involve children under 5 years old. Households devote significant resources (time and money) to securing access to clean water, in order to reduce these health impacts.
- Estimates of the economic costs of *climate change* vary widely. Stern (2007a) estimated costs of 14.4% in terms of per capita consumption equivalents[3], when both market and non-market impacts are included. Others (*e.g.* Nordhaus, 2007) have estimated much lower costs. While there is considerable uncertainty about the eventual costs of inaction with respect to climate change, few would doubt that climate change has the potential to have very important implications for the world economy – particularly in non-OECD countries. Reduced agricultural yields, increased sea-levels, and greater prevalence of some infectious diseases are likely to significantly disrupt these latter economies.
- Environment-related *industrial hazards* – such as oil spills and land contamination – are already generating significant costs of inaction. For example, experience in Europe and US indicates that the costs of cleaning up or restoring damaged ecosystems after industrial accidents have occurred can run into billions of Euros. Moreover, due to the irreversible nature of some of the associated impacts, the real losses to society will be higher than these direct financial costs (no matter how comprehensive the remediation efforts may be).

2 BOD is measured in terms of disability-adjusted life years (DALYs) – a common indicator used in cost-effectiveness studies in the health economics field.

3 This metric is calculated by assuming the consumption path associated with the future growth that would be assumed to arise in the absence of any economic impacts from climate change. Next, climate change impacts are considered, which are translated into lower future growth rates, and a correspondingly lower future consumption path. The "cost of inaction" is the difference between these two consumption trajectories [see Sterner and Persson (2007) for a discussion].

- While the economic risks associated with *natural disasters* (*e.g.* floods, hurricanes) are only partly attributable to environmental factors, and can only be partly reduced through public policy measures (*e.g.* mitigation of climate change, flood prevention measures), the costs of inaction in these areas can also be considerable – the World Bank (2006) has estimated that the costs of natural disasters for the poorest countries can be as much as 13% of annual GDP.

- The costs of unsustainable *natural resource management* – in terms of lost future benefits from resource exploitation – can be considerable too. For example, Bjørndal and Brasão (2005) conclude that inefficient management of the east Atlantic bluefin tuna fishery may be resulting in reduced fishery yields with a discounted value of USD 1-3 billion. However, the costs of unsustainable fisheries management extend well beyond these direct impacts on the resources themselves, to also include indirect impacts on "downstream" sectors and ecosystems.

Some of these costs are already being reflected in government, household, or firm budgets. Examples from the public sector include the increased public expenditures on health services due to air and water pollution; increased unemployment benefits for out-of-work fishers; remediation costs for contaminated sites; and the dykes needed to protect against flooding.

Other components of these costs are at least partly reflected in existing markets, even though they are not readily perceived as costs of environmental policy inaction *per se*. Examples include the effects of contaminated sites on adjacent property prices, the effects of air pollution on agricultural yields, or the cost of property insurance in coastal areas.

Still other elements of the costs of environmental policy inaction are not reflected in identifiable economic variables at all. Examples include the costs associated with the continued loss of marine and terrestrial biodiversity; as well as the "pain and suffering" associated with poor health.

There are several generic issues which make accurate estimation of the costs of inaction in the environmental domain more difficult than in other spheres of public policy. Particularly relevant issues include:

- *Uncertainty:* There is considerable uncertainty associated with all stages in the costing of the impacts of resource depletion and environmental degradation. It is important to reflect this uncertainty in the methodological approach that is adopted, and in the way the results of these studies are communicated (*e.g.* presenting confidence intervals, rather than central estimates). Studies which neglect to include estimates for particular kinds of damages, on the grounds of their uncertain nature, will likely result in underestimates of the costs of inaction. Similarly, the treatment of uncertainties associated with the technological trajectory of the economy can have considerable implications for the estimated costs of policy inaction (and action).

- *Irreversibility:* Once degraded, many environmental assets cannot be restored to their original condition. In the presence of these irreversibilities, assessments of the costs of inaction must include the cost of losing the potential benefits of exploiting the resource at any time in the foreseeable future ("option" value). Option values can represent an important proportion of the total estimated costs of inaction for some types of environmental problems.

- *Discount rate:* With the environmental impacts of inaction likely to extend over very long periods, it is necessary to compare the costs of inaction borne "far in the distant future" with costs that are borne "today". There are ongoing technical disagreements about the manner in which this rate should be determined. Depending on the rate that is assumed, the estimated costs of inaction can vary significantly. In the face of uncertainty concerning future interest rates and the future path of the economy, some analysts favour the use of a discount rate which declines through time.[4]

[4] See Weitzman (2001). Only a small minority of OECD Member country governments have adopted this approach in their policy evaluation guidelines. See Hepburn (2007) for an overview of prevailing practice.

- *Substitutability:* Up to a point, economic sustainability is compatible with the substitution of environmental resources for other inputs and goods. However, for many types of resources, there are limits below which further substitution could result in significant economic losses. In general, the less easily substitutable is the resource, the less sustainable will be a path of development which involves its exploitation - and the greater will be the costs of inaction associated with its degradation or depletion.

- *Equity and distribution:* Policy-makers need to take the distribution of environmental impacts into account, for two main reasons: (i) the costs of many environmental problems will generate significant impacts for relative wealth (both within and across countries); and (ii) there may be no means by which "winners" can compensate "losers". As such, an explicit assessment of the distributional impacts is often undertaken, bringing attention to the equity (not just the efficiency) implications of different policy interventions. The actual weighting of impacts has sometimes been also proposed, as a means to take distributional impacts formally into account when assessing the costs of inaction. By attaching a greater weight to impacts which affect the poor than those which affect the rich, this approach seeks to reflect society's aversion to inequality directly in the estimated costs. This approach can also have a considerable impact on the aggregate estimates of the costs of inaction. Although this approach is being used in some contexts[5], it is not endorsed by all OECD country governments.

- *Behavioural responses and adaptation:* The costs of environmental policy inaction also depend on how households, firms, and governments are likely to respond, in the face of changing environmental or economic conditions. Assuming that these actors are "completely myopic" is, of course, unrealistic, and will likely result in a significant *over*estimate of the costs of inaction. On the other hand, an assumption of "perfect foresight" (costless adjustments to changing environmental conditions) will likely result in significant *under*estimates of these costs.

And finally, even where the costs of inaction are deemed to be significant, it is important to recall that identifying specific areas where environmental policies need to be strengthened will require a careful comparison between the marginal costs of policy *inaction* with the marginal costs of *action*. Because this report does not examine the costs associated with policy *interventions*, it cannot, in itself, be used as a guide to the establishment of future policy priorities.

2. What is meant by "costs of inaction"?

2.1 Defining "inaction"

All OECD governments have already introduced policies to conserve scarce *natural resources and/or preserve environmental* quality. Defining policy "inaction" in the context of an area of public policy in which significant strides have already been made is not straightforward. Conceptually, there are at least three possible baselines that could be used to represent "inaction":

- a hypothetical scenario, in which it *is assumed* that there is *no environmental policy intervention whatsoever*;

- an assumption that *existing environmental policy continues* in its present form and at its present level of *stringency; an*d

- an assumption that credible commitments will be implemented that would *increase the level of environmental policy ambition in the future*.

While the continued implementation of environmental regulations and market-based instruments at their existing level of stringency can hardly be characterised as "inaction", adopting such a perspective is likely to be more pragmatic than ignoring the existing policy framework.

5 The UK *Green Book* (2003) is one of the few government documents which provide policy evaluation guidelines on the issue of equity "weighting". It notes the practical complications associated with applying such weights, but concludes that appraisers should, "where deemed appropriate, attempt to adjust explicitly for distributional implications".

This is also consistent with the methodology adopted in the OECD *Environmental Outlook to 2030* (OECD, 2008), in which the baseline modelling scenario assumes that "currently existing policies are maintained, but no new policies are introduced to protect the environment." This has the pragmatic advantage that it gives governments "credit" for actions they have already taken, but not for those they have simply promised (and may never achieve). However, using this definition immediately raises the question of what exactly is embodied in the *status quo* policy framework, and how this can best be modelled in a dynamic context.

Once the "baseline" policy scenario has been defined in general terms, it is then important to assess how economic agents are likely to *respond* dynamically to that scenario. This response will depend in part on the nature of the policy instrument(s) being implemented within the existing policy. Over time, different policy measures will involve different scale and substitution effects – both of which will eventually translate into a different shape and location of the costs of inaction pathway. Households and firms are also likely to respond to the changing environmental conditions that they face, and the nature of this adaptation to the state of the existing environment should therefore be reflected in the analysis.

2.2 Defining "costs"

There will be residual environmental consequences embedded in the "no new policies" assumption that has just been described. There are several different units (or metrics) in which these environmental consequences can be expressed, but the broadest distinction that can be made is between "physical" (ecological, health, *etc.*) metrics and "monetary" metrics. Metrics related to resource exploitation might include rates of deforestation, rates of water abstraction relative to availability, and assessments of the status of fish stocks. Metrics related to environmental degradation might include emission rates relative to assimilative capacity. Further downstream, impacts on such variables as health, material damages, and resource productivity may need to be assessed.

The standard procedure for assessing environmental impacts is environmental impact analysis (EIA). In the context of assessment of the costs of inaction, an EIA would measure the various environmental impacts in physical units (which will probably vary from one impact to another). A life-cycle analysis (LCA) amounts to performing an "extended EIA", with environmental impacts being measured across the entire life cycle of the environmental problem in question.

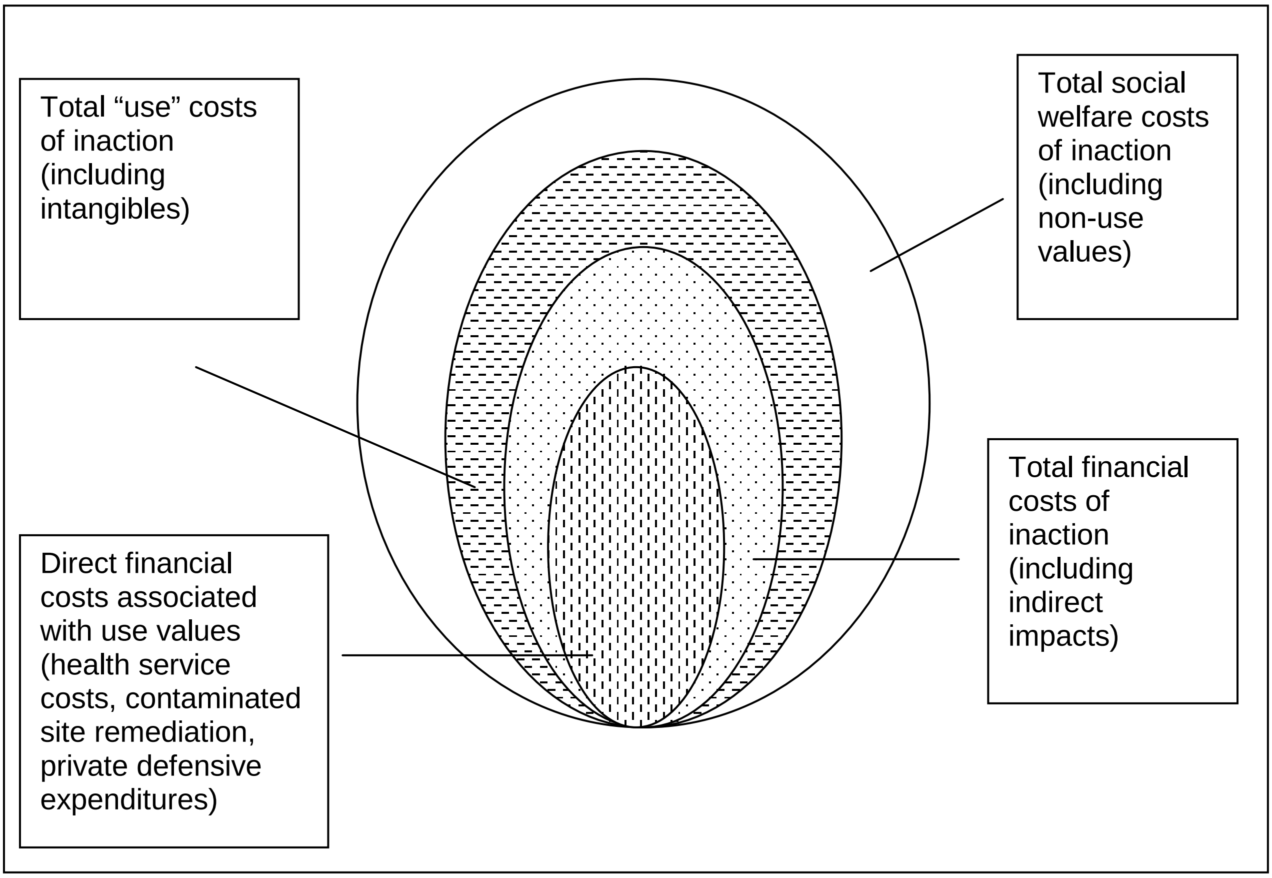
Taking the additional step of estimating the value of these impacts in monetary terms would then lead to two key advantages:

- Different types of impacts associated with inaction (*e.g.* loss of biodiversity or human health impacts) can then be compared using a common metric;
- The estimated costs of *inaction* can then be directly compared with the costs of *action* (*i.e.* the benefits of inaction).

However, actually taking this "valuation step" is not easy, partly because of uncertainties about the underlying environmental responses; partly because many environmental damages relate to impacts that do not have a market value. Even if there is a market value, this value may not reflect the "real" economic value. For example, the price of fish in the market may not reflect scarcity rents associated with its capture; the investment and operating costs associated with wastewater treatment plants may not reflect the full social costs associated with pollution.

Figure 1 illustrates one way of thinking about this problem. In the innermost circle, the *direct financial costs* of inaction associated with environmental degradation are captured. This might include expenditures on remediation and restoration, private and public health services costs, and private defensive expenditures. Going outward to the next bubble, other more *indirect costs* are included. These reflect some of the indirect costs of resource depletion and environmental degradation which are reflected in other associated markets (*i.e.* real estate and labour markets), as well as general equilibrium impacts.[6] In the next bubble, the costs associated with the loss of *environmental use values* that are not reflected in markets at all are included. This includes the non-market costs associated with pain and suffering and some aspects of environmental quality (aesthetics, visibility, *etc*.) And finally, the last bubble incorporates the loss of *non-use values*, such as existence values, as well as values associated with bequest and altruism. Estimates of the costs of inaction should, in principle, reflect all of these values.[7]

Figure 1. Unbundling the Costs of Inaction



6 For instance, in the valuation of public service health costs, it is important to take into account the means by which that service is financed. If it is financed through general tax receipts, the costs of inaction will be greater, the more distortionary the existing system of taxation.

7 For a discussion of valuation methodologies, see Freeman (2003).

3. Costs of inaction in selected areas of environmental policy

3.1 Air and water pollution

There are many costs of inaction arising from environmental degradation attributable to air and water pollution. With respect to *air* pollution, there are significant concerns associated with particulate matter (PM), ozone (O_3) and nitrogen oxides (NO_x). Other air pollutants of concern include lead and other metals, polycyclic aromatic hydrocarbons (PAHs), and ammonia (NH_3). With respect to *water* pollution, significant concerns include nutrients, dioxins, furans, and persistent organic pollutants, as well as metals such as lead, mercury and arsenic. At the global level, some of the most important costs of inaction arise from bacterial pollution due to inadequate water supply and sanitation.

Some empirical evidence is already available on the cost of some of these impacts. For instance, Kuik *et al.* (2000) estimated that a reduction in O_3 levels from present levels to natural background levels in the Netherlands would result in an economic surplus of EUR 310 million, with EUR 219 million of this accruing to consumers. Holland *et al.* (2002) assessed the agricultural costs of inaction, by comparing the effects of O_3 on yields in 2010 under the Gothenburg Protocol and a more stringent scenario that had been considered in the negotiations of the Protocol. Taking Gothenburg as “inaction”, the gross cost of not introducing the more stringent programme was estimated at EUR 259 million per year.

Lee *et al.* (1996) estimated that annual material damages from O_3 in the UK were approximately GBP 170–345 million per year. Olsthoorn *et al.* (1999) estimated that the materials damages in European cities associated with non-compliance of stationary sources with SO_2 air quality standards would be EUR 58 million per year. AEA Technology (2005) has estimated the material damages associated with air pollution (mainly acidic deposition) in the EU–25 (under current EU legislation) at EUR 1.1 billion in 2000. This exclude the costs of material damages to historic buildings and other sites of significant cultural heritage – which are likely to be considerable (Navrud and Ready, 2002).

However, studies which focus on a single type of outcome only capture a proportion of the total costs of inaction. At the aggregate level, Muller and Mendelsohn (2007) have estimated that the total damages associated with emissions of selected air pollutants (PM, NO_x, NH_3, SO_2, VOCs) from 10,000 major sources in the US are between USD 71 billion and USD 277 billion (0.7–2.8% of GDP). In the case of China, these costs are expected to be even higher. According to the World Bank (2007), the cost of the health impacts associated with air pollution in China represent about 3.8% of GDP, with much of this occurring in urban areas. Water pollution costs in China may also represent between 0.3% and 1.9% of rural GDP (depending on the “value of a statistical life” that is applied).

The most acute policy concerns associated with air and water pollutants relate to their deleterious impacts on human health. It has been estimated that the proportion of lung cancer attributable to toxic and carcinogenic air pollutants inhaled via particulate matter may be as high as 10% in Europe (Boffetta, 2006). Premature deaths in France, Germany, Italy, Poland and the UK associated with PM_{10} pollution in 2002 are estimated at between 40,000 and 75,000 annually. At the global level, outdoor PM pollution has been estimated to be responsible for approximately 800 000 premature deaths and 6.4 million years of life lost (0.7% of total years of life lost) each year (Cohen *et al.*, 2004). Levy *et al.* (2007) have estimated that there is a 0.4% increase in short-term mortality for each 10 ppb increase in 1-hour maximum ozone over the year.

Health impacts from bacterial water pollution are a particular concern in developing countries. At the global level, about 1.1 billion people do not have access to safe water supply and 2.6 billion people do not have access to adequate sanitation facilities (WHO/UNICEF, 2006). The associated health impacts are alarming: 1.7 million deaths, among which 90% were children under 5 years of age. Indeed, unsafe WSH is the world’s biggest child killer after malnutrition (Prüss-Üstün *et al.,* 2004). While the figures for OECD countries are generally much lower, some OECD countries are still significantly affected. Three-quarters (75.9%) of all deaths attributable to diarrhoeal disease in OECD countries are reported to have occurred in Mexico and Turkey.

With such impacts, it is not surprising to find that economic valuation studies indicate that the health impacts (morbidity and mortality) represent a very large proportion of the total costs of air and water pollution – often in excess of 90% (Table 1).

Table 1. The Relative Importance of Health Costs in Total Social Costs of Policy Inaction

Study	Context	Non-health costs included	Health %
ECOTECH (2001)	Gothenburg Protocol for Europe (SO_2, NOx, NH_3, NMVOC, PM_{10}, CO, CO_2)	Materials, Ecosystem	89%
Dziegielewska and Mendelsohn (2005)	25% improvement in air quality in Poland	Visibility, Materials, Cultural Heritage, Ecosystems	82%
USEPA (1999)	Benefits of Clean Air Act in US (NOx, VOC, SO_2, PM_{10}, $PM_{2.5}$, CO)	Materials, Visibility	96%
AEA (1999)	Gothenburg Protocol (SO_2, NOx, VOC, NH_3) in Europe	Materials, Crops, Timber	95%
Olsthoorn *et al.* (1999)	SO_2 - 50,000 tonnes (10%) reduction in Netherlands	Materials	97%
Muller and Mendelsohn (2007)	PM, NOx, NH_3, SO_2, VOC in the United States	Agriculture, Visibility, Materials, Recreation	94%

Many of these costs are reflected directly in market prices and national accounts. Most obviously, expenditures on medicines and health services will rise as a consequence of increased pollution. Some of these are reflected in public finance. In the UK, it has been estimated (UK Department of Health, 1999) that the total costs of respiratory diseases (GBP 566 million in 1996/97 prices) accounted for around 6% of National Health System hospital costs, and around 12% of the National Health System primary care expenditures. While environmental factors are clearly only one contributor to respiratory concerns, changes in pollution levels can have a significant impact on hospital admissions – a UK study found that a 1% reduction in the prevailing level of PM_{10} would result in a 0.14% reduction in respiratory hospital admissions (Maddison, 2005). A study by the Ontario Medical Association (2005) estimated that the healthcare costs in Ontario (Canada) associated with $PM_{2.5}$ and ozone were $CAD 507 million *per annum*.

The relationship between pollution, sick leave (or reduced activity days), and productivity has long been recognised. For instance, Samakovlis *et al.* (2004) estimated that an increase of 1 $\mu g/m^3$ in NO_2 emissions in Sweden would result in a 3.2% increase in respiratory-related restricted activity days. In a Norwegian study, Hansen and Selte (2000) found that the effect of reducing PM_{10} concentrations in Oslo from 24.5 $\mu g/m^3$ to 12.3 $\mu g/m^3$ would reduce the sick leave ratio by 7%. Earlier studies by Ostro (1983) and Hausman (1984) on the effect of total suspended particulates (TSP) in the US found much greater impacts. In the OMA (2005) study, lost productivity costs were estimated at approximately $CDN 375 million *per annum.*[8]

It is also important that the more intangible non-market impacts not be neglected in the assessment of the health costs of inaction with respect to air and water pollution. For instance, the relative importance of "pain and suffering" related to different environment-related health end-points can be considerable - as much as 90% of health costs can be attributable to this source in some cases.[9] Focussing only on the financial costs of illness – without taking broader welfare impacts into account – can result in a gross underestimate of the costs of inaction.

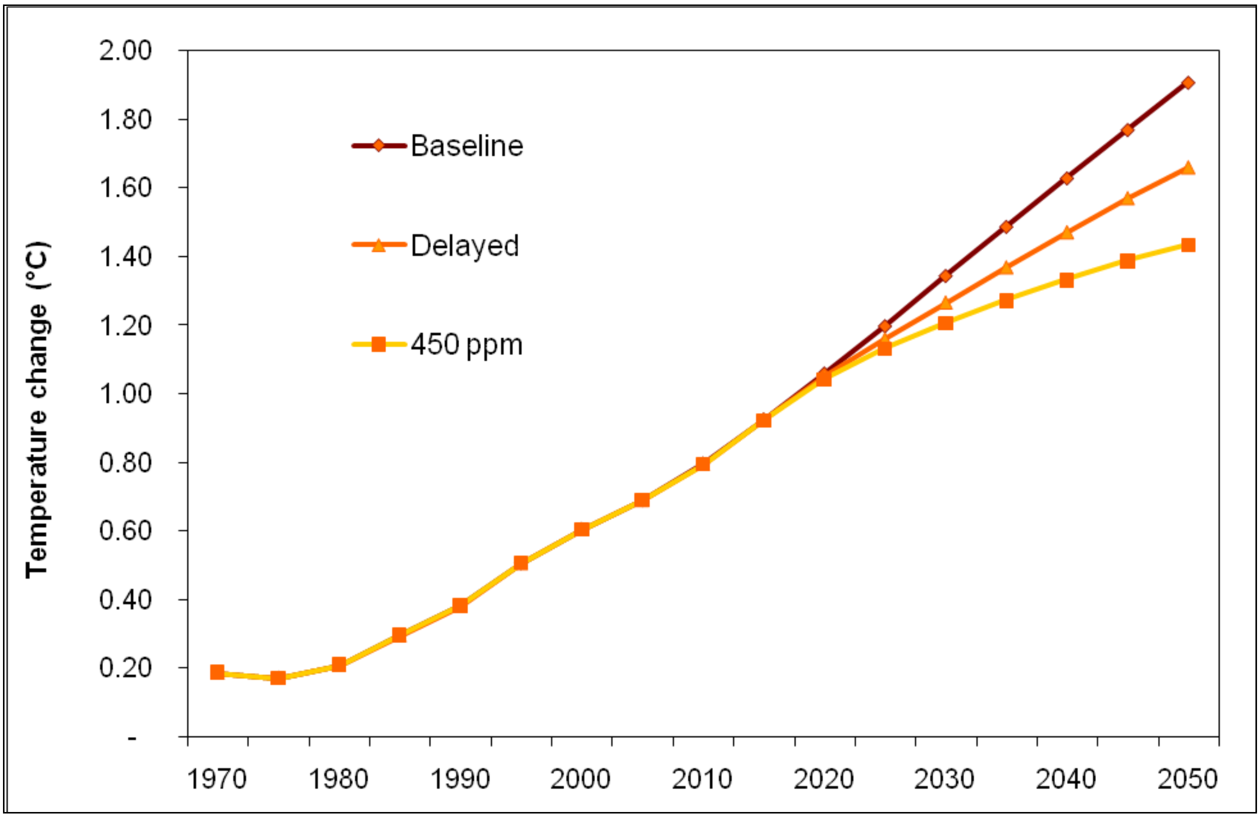
8 Total estimated costs (including pain and suffering and loss of life) were almost $CDN 8 billion *per annum*.

9 See Stieb *et al.* (2002) and Rabl (2004) for evidence from Canada and France, respectively.

3.2 Climate change

There is broad consensus that rising emissions of greenhouse gases (GHGs) from anthropogenic sources will lead to increases in global mean temperatures. In the International Panel on Climate Change (IPCC) 4th Assessment Report, it was assumed that a doubling of carbon dioxide concentrations from pre-industrial levels (approximately 280 ppm) would likely lead to a temperature increase of somewhere between 2.0°C and 4.5°C, although there is some danger of much greater changes in global mean temperature.[10] Figure 2 illustrates the anticipated mean global temperature change, based on emissions (historical and projected) that emerge from the "baseline" scenario in the OECD (2008) *Environmental Outlook to 2030*, as well as the result obtained by assuming two related policy simulations (stabilisation at 450 ppm; and delayed introduction of a USD 25/tonne carbon tax in 2020). In the former case, the associated tax would be about USD 100/tonne carbon by 2040.

Figure 2. Global mean temperature change under the Baseline, an aggressive mitigation scenario, and delayed action, 1970-2050.



Source: OECD (2008).

The impacts arising from this increase in global mean temperature (and associated changes in precipitation levels) are likely to be significant. First, there will be significant market impacts on productive sectors, such as agriculture, forestry, and energy. There will also likely be a variety of market and non-market impacts on human health (*e.g.* diarrhoea, malaria, heat stress), as well as marine and terrestrial biodiversity. Extreme weather events, such as floods and hurricanes, are likely to increase in intensity. And finally, climate change might also lead to catastrophes, such as turning off thermohaline circulation in the North Atlantic, sudden and rapid release of methane emissions, or melting of the Antarctic or Greenland ice sheets. (Table SPM.1 in IPCC (2007) (WGII) gives an indication of the likelihood of major projected impacts.)

10 IPCC WG1 (2007).

While there are several studies which have sought to estimate the marginal costs of GHGs per tonne of emissions, estimates of the total costs of inaction with respect to climate change are fewer in number, due to the significant modelling requirements associated with generating these estimates. In recent work using the PAGE2002 Model, Stern (2007a) estimated the costs of inaction in terms of "per capita consumption equivalents". Taking into account all potential impacts (market, non-market, extreme weather events, and catastrophic events), the discounted value of the costs of inaction with respect to climate change was estimated to be 14.4% in terms of "per capita consumption equivalents" in the scenario in which no new policies are introduced (*i.e.* "inaction").

Kemfert and Schumacher (2005) provided results for damage costs associated with a reference scenario in which no new climate policies are introduced. The total damage costs estimated in that study represent 23% of global world output in 2100. The damages associated with "delayed action" were also assessed - this latter case, no measures are assumed to be undertaken until 2030, at which point measures are introduced to ensure that the increase in temperature is not greater than 2°C. In this case, the damages in 2100 would be approximately 15% of world GDP.

Since the early 1990s, Nordhaus has produced a series of estimates based on the Dynamic Integrated Model of the Climate and Economy (DICE), the most recent of which are contained in Nordhaus (2007). His baseline scenario is one in which "no policies are taken to slow or reverse greenhouse warming" (*i.e.* consistent with the definition of "inaction" being applied in this report). The estimated discounted present value of damages for selected runs from the DICE model were USD 22.65 trillion. As a percentage of the discounted value of total future income, this is just over 1%. With a 50–year delay being assumed in the implementation of "optimal" policies, these damages fall by approximately 20%, relative to the "no policy" scenario.

There is, therefore, significant variation in the estimated costs of inaction associated with climate change in the current literature. This is hardly surprising, given the uncertainties involved with respect to both economic and ecological relationships over such a long time horizon. For some of the impacts in which the potential costs are potentially most important, it is difficult to provide credible probability distributions of the likelihood of their arising, so including these potential costs in valuation studies clearly represents a significant challenge to the research community. The interpretation of the results obtained is, perhaps, an even greater challenge to the policy community.

Some indication of the degree of uncertainty associated with the estimated costs of inaction can be obtained from a comparison of the results from existing work. Tol (2005) reviewed 103 estimates of the "social costs of carbon" (SCC) in the period 1991–2003. The very large range between the 5% and 95% confidence intervals reported in Table 2 give an indication of just how much uncertainty there is in these estimates - even within the peer–reviewed literature.

Table 2. Estimates of Marginal Cost of Carbon Dioxide Emissions (USD/tC)

	Mean Estimate	5% CI	95% CI
Base	93	-10	350
Peer-Reviewed	50	-9	245

Source: Tol (2005).

One of the biggest sources of “economic” uncertainty relates to the choice of discount rate. This choice has important implications for the magnitude of the estimated costs of inaction. In the case of Stern (2007c), the estimated costs (expressed in terms of per capita consumption equivalents) decreased almost four-fold if a discount rate of 2.8% were to be applied, rather than the 1.3% used as the general basis for that study.[11]

There is also considerable uncertainty about the probability of some potentially catastrophic impacts arising at different levels of warming. Examples include:

- Collapse of the thermohaline current (THC) in the Atlantic Ocean;
- Release of methane emissions from thawing permafrost or warmer sea-beds;
- Switch of the El Nino/Southern Oscillation (ENSO) to a permanent state; and
- Deglaciation of the Greenland and Antarctic ice shelves.

In addition to the sheer magnitude of these impacts, accounting for such events in the estimation of the costs of inaction is complicated by the fact that they could occur suddenly and/or lead to irreversible changes. Moreover, the uncertainty associated with the timing and likelihood of these impacts is quite different from other types of uncertainty associated with climate change. The degree of risk aversion that is being assumed has significant implications for valuing the costs of inaction.

Aggregate estimates can also mask wide variation across countries. In his study using the FUND model, Tol (2002) found a great deal of variation in the estimated economic cost of impacts across different regions. By 2200, Africa and Central and Eastern Europe would bear damages equal to 8% of GDP, with Latin America and South and SE Asia experiencing damages of 5%. Middle Eastern and Centrally Planned Asian countries are actually estimated to benefit from climate change. However, there is broad agreement that the most significant impacts are likely to be felt in developing countries, because of their particular climatic conditions, because of the particular sectoral composition of their economies, and because of their more limited adaptive capacities.

Downing *et al.* (2005) identified three types of countries likely to be most vulnerable:

- *Coastal deltas*, where dense populations are subject to increased coastal erosion, recurrent storm surges and cyclonic risk – Bangladesh is an example;
- *Semi-arid regions*, where increased water stress will put further strain on marginal agricultural/pastoral systems – the countries of the Sahel provide an example here; and
- *Small–island states*, where sea level rise and cyclonic risk threaten populations, perhaps inundating whole islands, such as in the South Pacific.

The greater vulnerability of poor countries (and often poorer households within countries) can also have important implications for the estimated costs of inaction. In their analysis of the distributional impacts of market damages from climate change, Mendelsohn *et al.* (2006) found that there is a distinct tendency for the poorest quartile of society (in terms of country populations) to bear the greatest burden, irrespective of the climate model being used. Weighting utility across different income classes - an approach suggested by some - can have significant implications for the estimated costs of inaction. For example, Stern (2007c) informally estimated that the effect of the application of equity weights would increase his estimate of the costs of inaction from 14.4%, in terms of per capita consumption equivalents, to approximately 20%.

[11] The assumed “pure rate of time preference” is increased from 0.1 to 1.5.

3.3 *Environment-related industrial hazards and natural disasters*

Environment-related industrial hazards and natural disasters include a broad range of types of phenomena, such as floods, hurricanes, oil spills, nuclear accidents, and land contamination. The costs of these hazards and disasters can be very high. The World Bank (2006) has estimated that, for the poorest countries, the cost of natural disasters represents more than 13% of annual GDP. Although only some of this amount is directly attributable to environmental factors that can be influenced by public policy, this proportion is likely to be increasing over time. To the extent that environment-related industrial hazards and natural disasters are affected by factors subject to policy control, they can be considered "costs of inaction".

The most evident type of cost takes the form of *ex post* remediation, restoration and reconstruction costs incurred following the event. Table 3 provides data on the cost of clean-up of selected oil spills in North America and Europe. Although significant, these are only a small proportion of the total costs of inaction - which include other elements such as losses to the fishing sector, lost tourism receipts and ecological damages at sea or along the coast.

Table 3. Clean-up Costs for Selected Oil Spills

	Volume spilled	Estimated cost	Cost per tonne
Amoco Cadiz (1978)	223,000 tonnes	134 million EUR	650 EUR
Exxon Valdez (1989)	35,000 tonnes	3,100 million USD	70,454 USD
Erika (1999)	20,000 tonnes	124 million EUR*	6,200 EUR
Prestige (2002)	77,000 tonnes	559 million EUR	10,666 EUR

Note: * Represents only the land-based component.

Source: Garza-Gil *et al.* (2006).

In Europe, annual expenditures on the remediation of contaminated sites represent approximately 0.05-0.1% of GDP in the countries for which data is available, although there are a small number of European countries for which these costs are much higher (EEA CSI, 2005) More significantly, this only represents approximately 2.5% of the total estimated remediation costs – the undiscounted value of costs of remediation is between 2% and 4% of a single year's GDP. Based on a sample of 257 sites on the USEPA Superfund National Priorities List, Hamilton and Viscusi (1999) estimated that the cost of remediation per site was over USD 25 million. Greenstone and Gallagher (2005) reported that, as of 2000, approximately USD 30 billion had been spent on cleaning-up Superfund sites.

In the case of natural disasters, the costs of reconstruction can be much higher. Although data on reconstruction costs is not readily available, figures from Swiss Re and the Insurance Information Institute suggest that during the 1970s and 1980s, annual insured losses from natural disasters were in the USD 3-4 billion range (Kunreuther and Michel-Kerjan, 2007). Much of this relates to reconstruction associated with material damages. Since the 1980s, the scale of insured losses from major natural disasters has exhibited a steep upward trend.[12] The most recent data also indicate that, of the 230 billion USD of economic damages inflicted by major *natural* catastrophes worldwide, a record amount of 83 billion USD was covered by insurance. On the other hand, the volume of insured losses from *human*-caused catastrophes (including industrial accidents) remained more-or-less constant over the entire period – approximately 5 billion USD.

[12] The extent to which this reflects market losses depends in part upon the "insurance density", and this varies widely across (and within) countries. For example, the data suggest that the ratio of insured losses to overall losses has been about 38% in the US, versus about 27% in Europe during the period 1980-2005. However, these figures vary by incident. While "insurance density" in the US is thought to be about 25-50%, the relevant figure in the case of Hurricane Andrew was approximately 65%. For Katrina, it was 27-33% (Munich Re, 2006).

The costs of reconstruction following a natural disaster depend heavily on market responses. Using a model which takes into account possible market rigidities in the adjustment to an extreme weather event "shock", Hallegatte *et al.* (2006) found that the overall impacts of extreme weather events are much greater than if a smooth adjustment is assumed (as is the case in many models). With sufficient frequency and intensity of extreme weather events, an economy may find itself in "perpetual reconstruction", with the economic impacts being amplified over time.

However, remediation, restoration and reconstruction usually only represent a sub-set of the costs of inaction. There will also be partial (in some cases, total) and temporary (in some cases, permanent) losses of the resources affected by the environmental damages. For instance, oil spills lead to the loss of commercial fishing opportunities; contaminated sites also lead to reduced land development opportunities. The resulting market and non-market recreation and amenity costs may be significant. Losses in terms of non-market (ecological) damages may also be considerable. For the particular spills mentioned above, the estimated costs of remediation represented less than 50% of the total estimated costs of inaction (Garza-Gil *et al.*, 2006).

There are good reasons why restoration and remediation costs frequently represent less than 100% of costs of inaction. On the one hand, it can be uneconomic to invest in full remediation or reconstruction following an accident – *i.e.* the *ex post* costs of remediation or restoration associated with returning the environment to its previous state would be exorbitant, and certainly greater than the *ex post* benefits. On the other hand, some damages are irreversible, and in such cases, it would simply not be feasible to return the environment to its previous state, irrespective of the cost.

Given that remediation, restoration, and reconstruction costs are likely to be considerable (and that damages can be irreversible), there is a strong case here for *ex ante* "prevention". The introduction of measures which reduce the frequency and severity of environment-related industrial accidents and natural disasters will often be less than the costs of restoration. For instance, technical standards for the maritime fleet and hazardous waste disposal facilities can have a significant impact on the probability and severity of environment-related industrial accidents. Liability regimes also have an important role to play in providing incentives for prevention. However, it is likely to be uneconomic (and often impossible) to reduce the risk associated with such events to zero.

In the case of natural disasters, upstream preventive measures have a more uncertain impact on the probability and the intensity of extreme weather events. While there is little question that climate change is an important contributing factor here, this relationship is not well understood. However, even if "risk" remains uncertain, vulnerability can be reduced. The World Bank and the US Geological Survey have estimated that the world-wide economic losses from natural disasters in the 1990s could have been reduced by USD 280 billion, if USD 40 billion had been invested in disaster preparedness, mitigation and prevention strategies (World Bank, 2004).

3.4 Natural resource management

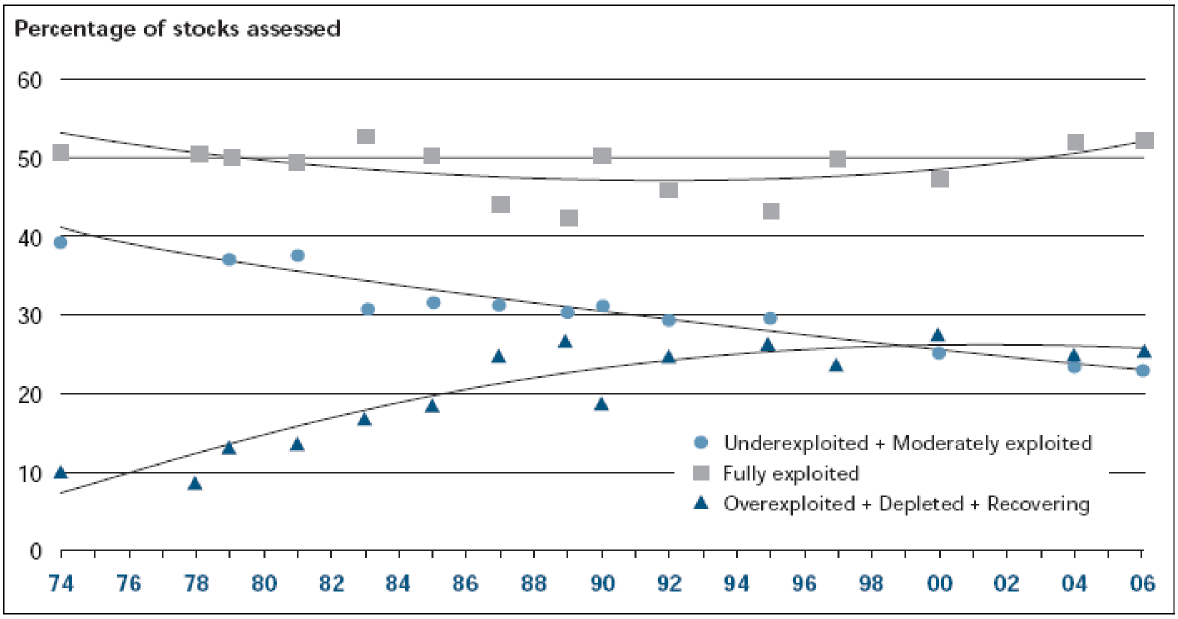
"Natural resources" include those which are renewable (*e.g.* forests, fish stocks) and those which are non-renewable (*e.g.* oil, coal). The costs of inaction associated with management of marine fisheries and groundwater were the resources selected for review in this report. While the former is unquestionably a "renewable" resource, the latter has an ambiguous character. Although some groundwater is replenished very quickly, in other cases, recharge can only take place over millennia, with the implication being that groundwater is sometimes better characterised as a non-renewable resource, analogous to mineral deposits and fossil fuels.

The costs of unsustainable use of natural resources can be considerable. Most obviously, this will include the direct costs associated with the loss of the resource in question. For instance, exploiting a fish stock to commercial extinction will result in the loss of yields. Rapid groundwater depletion may encourage saline intrusion, rendering the aquifer unusable for the foreseeable future. Given the importance of some natural resources to economic development (especially in local communities), significant public expenditures may be incurred in order to mitigate the welfare impacts of unsustainable resource exploitation. And finally, there are likely to be a wide variety of costs associated with impacts on non-use values, such as those associated with the loss of ecosystem values.

For *marine fisheries*, inefficient management arises out of the practical and political difficulties associated with excluding access to potential users of the resource. In such a context, the rate of exploitation will be excessive, and socially inefficient. Policy "inaction" will therefore arise in situations in which access to the marine resource is not sufficiently controlled. Constraining access can be done directly (*i.e.* through property rights creation), or indirectly (*i.e.* through regulatory or financial measures).

The consequences of inadequate fisheries management are reflected in the status of marine fisheries stocks. Figure 3 illustrates that, although the proportion of fully-exploited stocks has remained more-or-less constant over the last three decades (at about 50%), there has been a notable increase in the proportion of over-exploited and depleted stocks (from 10% in 1974 to 25% in 2005). According to the FAO (FAO, 2007), "the maximum wild capture fisheries potential from world's oceans has probably been reached."

Figure 3. Global Trends in the State of World Marine Stocks (1974-2006)



Source: FAO (2007).

In addition to the costs in terms of the non-use values associated with unsustainable fisheries management, the financial market costs can be considerable. Bjørndal and Brasao (2005) have estimated that the net present value associated with retaining the existing (ineffective) fishery management regime (*i.e.* total allowable catch and restrictions on gear selection) for East Atlantic bluefin tuna is one-third what would be achieved from an optimal regime. This is estimated to result in a loss of approximately USD 2 billion.

Based on a study of 13 "overfished" fish stocks in US waters, Sumaila and Suatoni (2006) assessed the lost direct use values (commercial fishery yields and recreational fishing) associated with continued excessive fishing effort, and found that the lost NPV arising from the continuation of the existing management regime was USD 373 million (USD 193.7 million, instead of USD 566.7 million).

In Canada, the closing of the Atlantic cod fishery in 1992 also had important economic impacts. Foregone income reached an estimated CAD 250 million in the short-term. In the long-term, the forgone potential annual income relative to a sustainable fishery was an estimated CAD 1 billion per year (MacGarvin, 2001). However, the impact was mitigated by increased exploitation of the latent potential of shellfish fisheries which had not previously been exploited. As a result of these market adjustments, the total value of processed fin and shellfish actually increased. This highlights the importance of accounting for adaptation in the valuation of the costs of inaction.

It has been estimated that about 30,000 people lost their jobs at the height of the cod fishery crisis, including 10,000 fishers. In response, substantial public funds were spent on income support (including fishers' unemployment benefits) and government assistance programmes (expenditures towards restructuring, sectoral adjustment, and regional economic development). An estimated CAD 3.5 billion was spent on these programmes (OECD, 2006).

Similar issues arise in the case of *groundwater*. In the OECD countries, the largest aquifers in terms of volume include the High Plains Aquifer (US) and the Great Artesian Basin (Australia). Other economically important aquifer systems include the Alsatian and the Pannonian aquifers in Europe, the Denver Basin (Colorado), Central Valley (California) and Edwards aquifers (Texas) in the US, and the Valle de México aquifer system in Mexico (WWAP, 2007). Groundwater accounts for over 97% of all the freshwater available on earth. The relative contribution of groundwater to a country's total usable freshwater endowment varies greatly across OECD countries – from less than 6% in Finland and Japan, to about 27% in Mexico and Turkey, and to more than 50% in Hungary and Denmark.

In the context of groundwater management, "inaction" can best be described as resource management where prices of groundwater abstraction do not reflect its scarcity rent and associated environmental externalities. The consequent depletion of the resource directly affects users (domestic, agriculture, commerce and industry). It can also have indirect impacts on regional economic activity, such as lost earnings of workers and foregone profits. There can also be important environmental externalities which result in significant costs (*i.e.* subsidence and salination). And finally, there can be costs associated with damages to non-use values, such as the life-support function of water. In practice, policy measures often encourage, rather than constrain, groundwater abstraction (*e.g.* right of capture; "first-in-place" or "first-in-right" systems). Even fewer systems incorporate scarcity rents and externality costs in water prices.

Groundwater used for irrigation represents a major economic resource. In the US, 81% of total consumptive use of groundwater is for irrigation (USDA, 2007). Global abstraction of groundwater for irrigation is estimated to be 900 cubic kilometers, having growing almost ten-fold in the last five decades; groundwater-irrigated agriculture represents almost 30% of total irrigated area, and 9% of total cultivated land in Asia (Shah *et al.,* 2007).

Thus, the implications of the depletion of groundwater resources for the agricultural sector are potentially very great. About 8% of food crops already grow on farms that use groundwater faster than the aquifers are being replenished (Postel, 2001). Declining groundwater supplies from the Ogallala were largely responsible for the loss of an estimated 1.435 million acres of irrigated cultivated cropland between 1982 and 1997 in the State of Texas. In some areas, irrigated acreage is predicted to drop 50% by 2030, if current extraction rates continue (USDA, 2007).

The situation in non-OECD countries is, if anything, worse. In China, the costs of salination and excessive rates of resource exhaustion have been estimated to be 50 billion RMB (World Bank, 2007). This amounts to approximately 0.3% of annual GDP. Globally, it has been estimated that salination of groundwater affects agricultural productivity on 22 million ha of land, particularly in China, India, the Commonwealth of Independent States, the US, and Pakistan. The farmers affected by this problem lose up to USD 11 billion per year as a result (UNEP, 2003).

Costs associated with the depletion of groundwater are also likely to be reflected in the availability and costs of drinking water. According to one estimate almost half of the world's population relies on groundwater for drinking water (Shah *et al.,* 2007). In the US, groundwater provides 35% of the public supply of drinking water and as much as 80% of drinking water in rural areas (Boyle, K. J. *et al.,* 1998). In the EU, groundwater provides about 70% of piped water supply (WWAP, 2007). Groundwater also provides about one-third of drinking water supplies in the Asia-Pacific region and Central and Southern America (Table 4). Many of the world's large cities depend heavily on groundwater.

Table 4. Percentage of drinking water supply obtained from groundwater

Region	% Groundwater	Population served (millions)
Asia-Pacific	32	1000-2000
Europe	75	200-500
Central and Southern America	29	150
USA	51	135
Australia	15	3
Africa	n.a.	n.a.
World	-	1500-2750

Source: UNEP (2003).

This can result in a vicious circle, with fast-growing cities increasingly being dependent upon a depleting groundwater resource, necessitating the exploitation of costly surface water substitutes. For example, in the Mexico City Metropolitan Area water is being withdrawn from the aquifer under the city at twice the rate of recharge (*i.e.* 45 m^3/s and 20 m^3/s), with the water table lowering by approximately 1 metre per year, and land subsidence of as much as 10-40 cm/year occurring in some parts of the city (Tortajada *et al,* 2003). However, this is still far from sufficient to meet current demand, so water is being transferred from ever-more-distant sources, including the Cutzamala River. Given the topography of the region, this results in significant investment (more than USD 1 billion annually) and pumping (more than USD 60 million) costs.

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