ANCILLARY BENEFITS AND COSTS OF GREENHOUSE GAS MITIGATION

AN OVERVIEW[1]

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1. Introduction

Much of the debate over global climate change involves estimates of the direct costs of global climate change mitigation and the merits of various policies proposed to mitigate greenhouse gas emissions (GHG). Recently, this debate has broadened to include the issue of ancillary benefits and costs. It is generally understood that policies to reduce GHGs can have positive and negative "ancillary effects" on public health, ecosystems, land use, and materials and that such effects, if they can be monetized, can appropriately be subtracted from (or added to) mitigation cost to assess the social cost of such policies. Despite agreement that ancillary effects can be important, terminology to describe the effects and methods for estimation and valuation are in need of development and standardisation.

Whatever terminology is used to depict the indirect consequences of GHG mitigation policies, it is recognised that these effects can be constructive *or* harmful. Positive ancillary effects could result from, for instance, mitigation policies that reduce health- or environment-damaging emissions of conventional pollutants. Negative ancillary effects might result from those policies that increase health-or environmental damages , such as increased reliance on diesel fuels, which have lower greenhouse emissions than petrol but can increase health and environmental risks. These ancillary effects are not always well understood, and, until recently, have rarely been systematically quantified and valued. They are therefore seldom integrated into the development of GHG policies. Recent studies suggest that under some scenarios where baseline conditions include relatively high levels of pollution and inefficient abatement technologies, ancillary benefits of GHG mitigation policies can be of the same magnitude as the costs of proposed mitigation policies. Thus, the failure to consider ancillary effects may hamper the development of sound policy making.

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1 The authors of this paper acknowledge the contributions of the authors who presented their papers at the workshop entitled "Ancillary Benefits and Costs of Greenhouse Gas Mitigation". This overview paper draws extensively on the presentations of Luis Cifuentes, Richard Morgenstern, and David Pearce. It also draws on other papers presented in the workshop and where necessary to fill in the analytic gaps, on the wider literature on this topic. The paper is intended to be a broad overview of relevant issues rather than simply an overview of the workshop papers. The overview paper was developed after the meeting; thus it was not presented nor was it discussed at the meeting.

On 27-29 March 2000, an international workshop to consider these issues was held, in Washington D.C. The workshop was designed to provide information for the ongoing assessment efforts of the IPCC and other national and international agencies, to bring the ancillary benefits and costs of policies more clearly into the climate change debate, and to establish research priorities. This event brought together many of the leading experts on this topic to discuss their work and identify key issues for further analysis. The three days of the workshop covered methodologies and frameworks, case studies, and links to policy-making. While the workshop left many issues for further work, it advanced understanding on common elements of an analytic framework for addressing ancillary benefits and costs and facilitated a dialogue between analysts in this field. This summary report sets out some of the major issues addressed, areas of wide agreement and continuing controversies arising from the workshop and from the wider literature.

Section 2 discusses the basis for a common terminology and framework for analysis of ancillary effects, and sets out the key methodological issues involved. Section 3 provides a classification of potential ancillary effects. Section 4 then draws on these frameworks to examine existing empirical studies of ancillary effects. Section 5 discusses how ancillary effects analysis can impact on policy design and choice, and how ancillary effects analysis can be usefully integrated into policy-making processes. Finally, Section 6 outlines key steps in promoting better understanding and consideration of this important topic in policy-making.

2. Methodological and conceptual issues

2.1 Terminology

Ancillary benefits of GHG mitigation policies have been defined as the social welfare improvements from greenhouse gas abatement policies other than those caused by changes in greenhouse gas emissions, which incidentally arise as a consequence of mitigation policies[2]. This concept is not unique to climate change policy. However, the heterogeneous sources of GHG throughout the economy, their intricate economic impacts, and the global nature of climate change, make the assessment of ancillary benefits more complex than in many other policy areas. Also, due to the large uncertainties about the long-term and direct impacts of climate change, and the best methods for valuing these impacts, analysis of the shorter-term, non-greenhouse effects seems especially important if governments are to implement sensible policies in this area.

The different terms used to depict ancillary effects reflect differences in their entry into the policy process. Thus, the term ***co-benefits*** (sometimes also referred to as multiple benefits), signals (monetised) effects that are taken into account as an explicit (or *intentional*) part of the development of GHG mitigation policies. The term ***ancillary benefits***, indicates impacts that arise *incidental* to mitigation policies. (See Figure 1a and 1b). This paper uses the term ancillary effects to denote those impacts that occur as an incidental consequence of changes in GHG emissions. This should be understood to include negative impacts, or costs, and does not imply that the ancillary effects are necessarily of lesser importance than greenhouse gas abatement. The workshop participants appreciated that distinctions between ancillary benefits and co-benefits have not always been consistently followed. There was general agreement about the need to promote finer analytic distinctions between these terms.

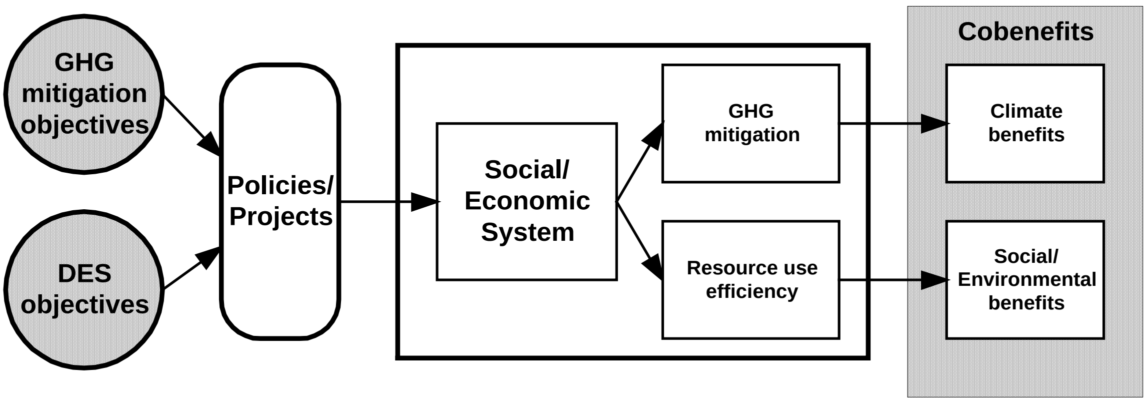
2 Or, in the case of climate change adaptation policies, outcomes other than reduced vulnerability to the potential impacts of climate change - this is discussed further below.

Different scientific literatures use different terms for distinguishing physical and economic effects. The term impact in the paper always means physical effects and can be an improvement or detriment, the term ancillary benefits means the value to society of obtaining the physical improvements and the term ancillary costs means the value lost to society from negative outcomes, such as making health worse. Effect is used in this paper to be the most general term, meaning both physical and economic outcomes unless otherwise stated.

There appear to be three classes of literature regarding the costs and benefits of climate change mitigation: (1) literature that primarily looks at climate change mitigation, but that recognises there may be benefits in other areas; (2) literature that primarily focuses on other areas, such as air pollution mitigation and recognises there may be benefits in the area of climate mitigation; (3) literature that looks at the combination of policy objectives (climate change and other areas) and looks at the costs and benefits from an integrated perspective. Each of these classes of literature may have their own preferred terms.

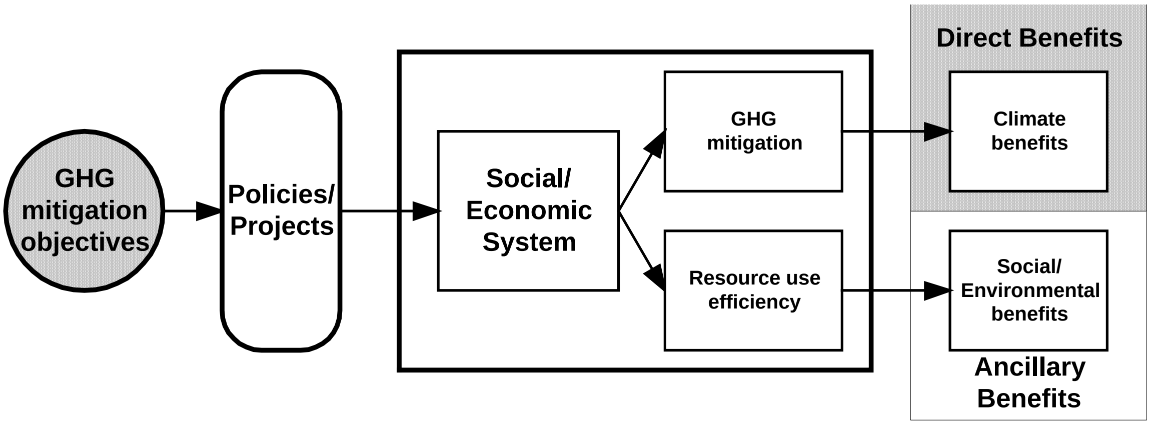
The IPCC and others are using the term "co-benefits" when speaking generically about the issues covered in class (3), in particular the integration of consideration of policies to mitigate climate change with concerns about sustainable development and other policy objectives. The terms "ancillary effects" or "ancillary benefits and costs" are used in this paper when addressing the class (1) and (2) literature. The class (1) literature appears to be the most extensive and it is this literature on *ancillary benefit and costs* of greenhouse gas emission mitigation that is primarily covered in this paper.

Figure 1a. **Co-benefits of GHG mitigation**[3]



[3] Figures 1a and 1b are adapted from discussions of Working Group III of the IPCC, Capetown June 2000. The term "DES" depicts development, equity and sustainability.

Figure 1b. **Ancillary benefits of GHG mitigation**



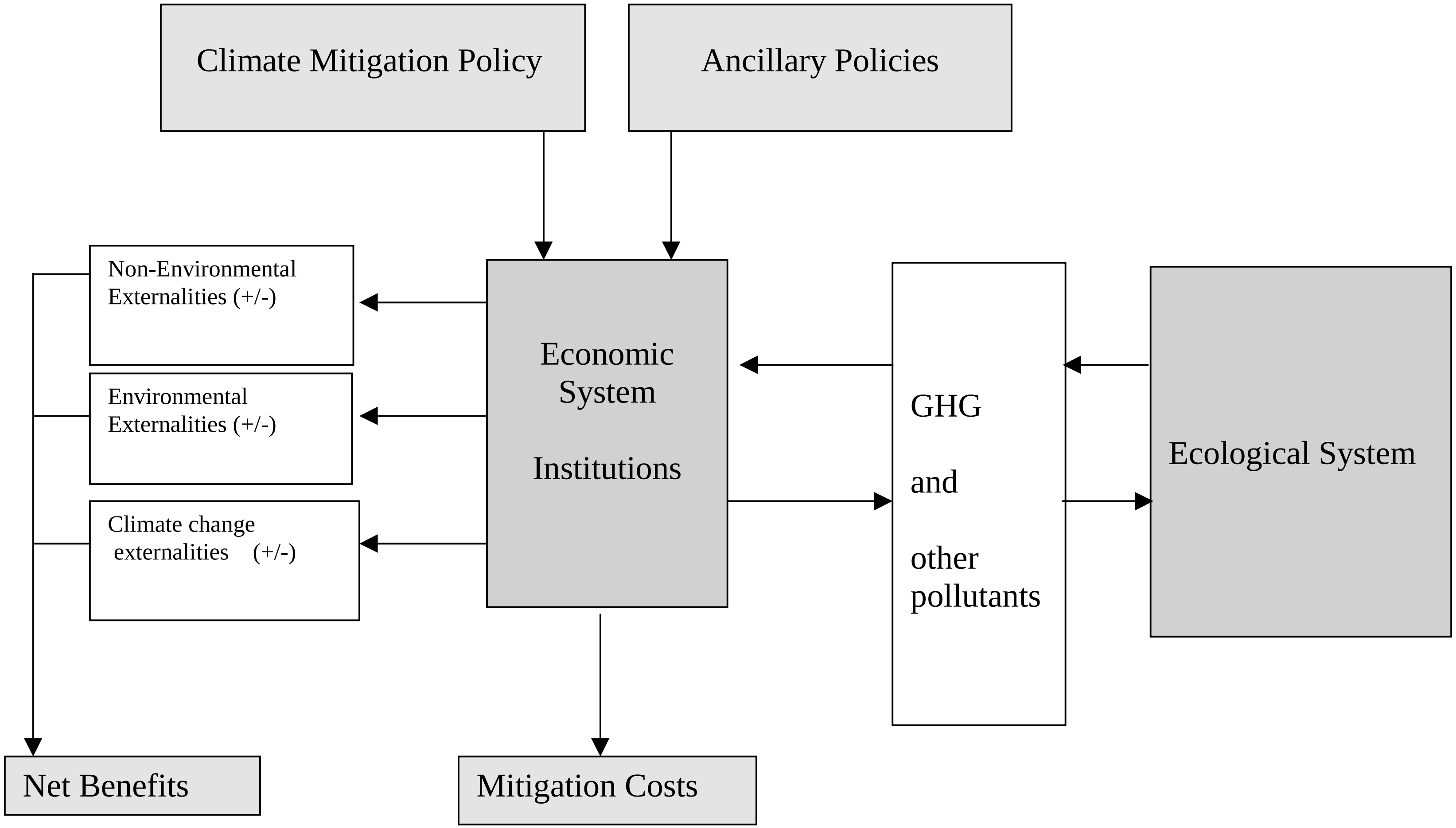
2.2 Conceptual framework

Whichever terminology/approach is used, Krupnick et al (2000) indicate the central importance of the economic and institutional system to determination of ancillary effects. Figure 2, provides a graphical representation of the general approach to ancillary effects analysis. Climate mitigation policies operate through an economic and institutional system within a country that leads to reductions in GHGs, changes in other pollutants, and mitigation costs. The emission changes work through an ecological or environmental system that eventually feeds back into the economic system. Then, depending on conditions of the economic system and its institutions, such as labour markets, tax systems, existing environmental and other types of regulations (represented by the box labelled "Ancillary Policies"), these feedbacks may become environmental externalities (such as changes in conventional air or water pollution), non-environmental externalities (such as employment effects) and, of course, climate change externalities (such as leakage of carbon emissions).

The importance of the economic system and institutions argues against the methodology used in early ancillary effects analyses, which implied fixed coefficients between greenhouse emissions and other effects. Different technological and regulatory structures, and differences in economic parameters, will make these relationships situation-dependent. For example, Barker and Rosendahl (2000) showed that changes in assumptions about the future price of oil can drastically change the measurement of ancillary benefits as higher prices will themselves drive many of the improvements which climate change policies might support.

Consideration of the economic system and institutions adds considerable complexity to the analysis of ancillary effects, and has implications for the types of analysis chosen. It raises questions of balancing analytical completeness with the need to limit the time and resources spent on analysis. Development of the analytic baseline - which includes projections of many of these institutional and socio-economic parameters - is clearly a vital element in analysis of ancillary effects since these baseline issues determine the environment in which climate change policies will have their effects.

Figure 2. **Ancillary benefits and costs of climate change mitigation: A conceptual framework**



2.3 Baseline issues

Assumptions about what will happen in the absence of any explicit policies critically determine the scope and scale of any potential ancillary effects. Morgenstern (2000) identifies and discusses five issues where baselines could be significant in assessing ancillary effects. These issues are distinct from those that are generally considered in the baselines of large-scale economic models. The first three of these issues - non-greenhouse policies, technology and economic development - are all very closely interconnected. Changes in any of these will generally have direct implications for the others. The final two - demography and natural activities - also have such linkages, but of a far smaller order, so these can usefully be treated as exogenous to GHG policy evaluation.

2.3.1 Non-greenhouse policies

Current and assumed future laws, policies, and regulations (and degree of compliance) play a major role in shaping the relevant ancillary effects baseline. As a general rule, the more abatement of ancillary effects that occurs in the baseline, the lower will be the measured ancillary effects of climate change policy. As an easy example, if it is assumed that leaded petrol will be phased out for air quality reasons, then climate change policies that reduce travel or increase vehicle efficiency will have no ancillary lead abatement benefits. On the other hand, if it is assumed that consumer preferences for environmental quality will increase over time, or the potentially exposed population will increase, then the estimated benefits of ancillary emissions reductions will be higher than if these changes had not occurred. For example, when full account is taken of the U.K.'s national target under the Long-Range Tranboundary Air Pollution Convention's Second Sulfur Protocol, Burtraw and Toman (1997) estimate that the mean value of the ancillary effects calculated by Ekins (1996) for European nations declines by about one-third.

Two particular issues in relation to policy baselines include:

> New regulatory activity – The pace and stringency of regulatory activity can directly affect the size of ancillary effects. More stringent regulations reduce the amount of pollution to be controlled, for instance. In addition, the precise form of new regulations can affect the size of ancillary effects. For instance, in response to a GHG mitigation policy, the hard cap on SO_2 emissions in the US SO_2 trading program results in the counting of avoided SO_2 abatement costs as ancillary benefits but not health improvements.
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> Compliance with regulations - It is not generally appropriate to assume that all emitters will be in full compliance with new or existing standards. In some developing countries where economic or other development goals take priority over environmental considerations, compliance cannot be expected to be high. Even where there is a strong history of enforcement, non-compliance can exist. For example, more than half the US population lives in areas that are currently in violation of the ambient ozone standard.

Although environmental policy is an important element of the baseline it is not the only relevant area of concern. For instance, income distribution, market reforms in energy and transport, health policies, and the location of economic activity can all have impacts on future levels of ancillary effects. At a minimum, such policy assumptions need to be made explicit.

2.3.2 Technology

While assumptions about economy-wide rates of innovation and technology/efficiency improvements are generally transparent in macro-level analyses of the costs of GHG reductions, more detailed estimates may be needed for ancillary effects analysis. Often, the effect of economy-wide assumptions on future baseline emissions is not transparent, and sometimes it is not even addressed. For instance, assumptions about the expected rate of vehicle stock turnover, fuel quality, and the decay rate of catalytic converters as the fleet ages are all critical components for estimating baseline ancillary emissions, but are not generally stated or even addressed in ancillary effect calculations.

2.3.3 Economic development

Macro-economic assumptions that are employed about baseline levels and growth rates of aggregate economic activity (GDP) will critically affect estimates of the direct benefits and costs of GHG mitigation policies. With respect to the calculation of ancillary benefits, these assumptions of large-scale factors do not generally permit specific inferences to be made about potential impacts. . Disaggregation at the industry and regional level is clearly critical to understand shifts from pollution-intensive industries to the service sector. In addition, to get a full understanding of the ancillary effects it is important to understand the size of the population exposed to conventional pollution. This, in turn, requires an understanding of the spatial location of the emissions vis a vis the population.

2.3.4 Demography

While large-scale economic models routinely consider overall population trends, they generally do not take account of a number of other demographic factors that are important to the consideration of ancillary effects. For example, continued improvements in the health status of the population, or access to universal health care, will affect the estimation of ancillary effects in a number of ways. Increasing urbanisation tends to expand the size of the population exposed to high pollution levels. The overall ageing of the population can also affect the estimate, as the aged are more vulnerable to health damaging effects of pollution.

2.3.5 Natural activities

A final baseline issue concerns the natural resource baseline, particularly the assimilative capacity of the natural system. Many ecological processes are relatively poorly understood, but will greatly affect the calculation of ancillary effects. For example, assumptions about the time to nitrogen saturation in soils greatly affected the percentage of projected chronically acidic lakes in the Adirondacks, New York, USA. Insofar as ecological impacts are an important source of ancillary effects, better understanding of these systems is required to accurately estimate any benefits/costs.

2.4 Other key issues in ancillary effects analysis

2.4.1 Developed and developing countries

Most of the ancillary effects literature (again, here we mean effects to include physical impacts and their monetary value to society) until quite recently came from developed countries, especially the US and Europe. Many of the data used are based on detailed, national assessments of health and other impacts and values. As examination of ancillary effects is extended into developing countries, a number of difficulties arise.

First, there is the question of which effects are direct and which are ancillary. In developed countries with quantitative commitments under the Kyoto Protocol, governments are compelled to consider alternative approaches to meeting Kyoto targets, their costs and benefits. So, there is little fundamental difficulty with the consideration of ancillary effects of climate policies in principle. However, for many countries without specific climate abatement commitments, there is a range of higher priority development and environmental concerns. In these countries, governments may be hesitant to consider health impacts related to air pollution, for example, as ancillary to climate change mitigation, since policies are far more likely to be driven by health concerns than climate change. In this instance, climate policies may not be the most effective way to address these health concerns. Raising the perspective of ancillary effects of climate policies can give a skewed view of the most efficient policies to pursue sustainable development more broadly. On the other hand, if developing countries can participate in a climate mitigation policy, through the Clean Development Mechanism (CDM) where developed countries pay for GHG mitigation in rapidly developing countries, then ancillary effects may consequently arise. Whether such steps are the most efficient from the perspective of sustainable development is less important in this context. This issue is closely related to that of baselines. If non-climate policies, such as controlling regional air pollution, are a priority for a country, then those policies should be carefully considered in estimating the baseline conditions for ancillary effects.

A second concern that arises in assessing ancillary effects in developing countries is questions about the relevance of using health and economic studies obtained in developed countries to project effects in other regions. A number of studies in developing countries employ health estimates based on work produced primarily in the U S and Europe, adjusted for GDP and sometimes other factors. It is not clear that such an approach accurately reflects differences in culture, priorities and assessment of risk. Seroa da Motta (2000), for example, shows that approaches using transfer of economic assumptions and data and those based on indigenous data provide widely diverging assessments of the value of health impacts. This study also indicates the difficulties in collecting accurate and comprehensive data in developing countries. This leaves researchers in a quandary of not being able to easily collect indigenous data, but not being confident of reliance on data transfers from developed countries. In relation to the public health impacts of various scenarios, there is a growing and fairly robust literature indicating that the scale and magnitude of physical effects is fairly well understood (Davis et al., 2000). However, it is clear that more work on appropriate data for developing countries is required before results from these nations can be accorded a high degree of reliability.

Ancillary effects should be understood and estimated in geographic and time-specific context. For many developing countries the problem is not simply ignorance about the existence of ancillary effects. Rather, decision makers have to weigh the potential ancillary effects of proposed GHG mitigation policies against other priorities. If the inclusion of ancillary effects does not tend to increase the short-term welfare of the community/society, it is unlikely that the mitigation option would be adopted. This may be the case in those developing countries where basic needs are yet to be satisfied.

2.4.2 Comprehensiveness of effects

In order to ensure that analyses of potential ancillary effects are integrated into the policy process, it is important to consider as many types of ancillary effects as practicable. Section 3 identifies four categories of ancillary effects: health, ecological, economic, and social. To date most research has focused on health, while limitations of both methods and data have constrained the ability to estimate the other benefit categories. More research is needed in these areas. Future work may confirm the general view that health benefits are indeed by far the most important source of ancillary benefit. However, for the moment this conclusion is chiefly a result of the fact that health impacts have been well studied and valued, in contrast to ecological, archaeological or other materials impacts, for example.

It is important to include the full array of potential impacts in the analysis of ancillary effects. For instance, omitting consideration of the environmental risks from greater reliance on nuclear or hydroelectric power, for example, could bias ancillary benefits upwards. Burtraw and Toman (1997) show that avoided costs may be an important and growing source of ancillary benefits and that is it important to identify and quantify their range. For many effects, such as those relating to cultural values of historic preservation, it may never be possible to fully examine all ancillary benefits and costs.

Comprehensiveness can also affect the nature of measures taken in different sectors. For example, if only health impacts are examined when looking at transport policies, measures such as fuel efficiency or alternative fuels that affect technology but not behaviour may be favoured. But if effects on congestion and vehicular fatalities, and reduced energy efficiency, are also included, measures to alter transport behaviour may well become more attractive, even if they are not the most cost-effective measures when looking at greenhouse gas reductions or air pollution reductions alone.

Comprehensive coverage is important within classes of ancillary effects as well as between them. Often only a subset of the relevant pollutants is considered in ancillary pollutant studies. It is now widely recognised that multiple pollutants may yield significant ancillary effects. The more recent US and European studies have focused on NO_x, ozone, SO_2, and PM_{10}. Given the importance of NO_x for the formation of fine particle (secondary pollutants), this is a critical addition.

Of course, pollutants of interest can vary significantly by country. For example, in some developing countries where direct combustion of coal is still prevalent in the household sector, both indoor and outdoor exposures may be important. Similarly, there may be significant ancillary effects associated with reduced lead exposure in a country such as Chile, or the other nearly 100 countries where leaded gasoline continues to be used as an octane booster in gasoline (Dessus and O'Connor 2000).

2.4.3 Ancillary costs (i.e., negative ancillary effects)

In addition to considering the full range of sources of ancillary benefits, it is also vital for analysts to consider ancillary *costs*. These can arise both from increases in externality-causing activities as well as changes in the spatial distribution of emissions. For example, while there are possibilities for increasing employment in some sectors through greenhouse abatement activities, these can also lead to a drop in employment in others. A loss of employment or income has been associated with worsened health status, including alcoholism, spouse abuse, and mental health problems (Viscusi, 1994; Perkins, 1998; Lutter and Morrall, 1994; Portney and Stavins, 1994). Consequently, the negative impacts on employment or income in some sectors may have social consequences that are not captured in economic models. On the positive side, ancillary effects should also account for any benefits arising from increases in employment or income. The point is that there is potentially a range of ancillary costs or benefits in this area.

Replacement of coal with other energy sources is often cited as a GHG abatement policy with many ancillary benefits. However, there is also potential for ancillary costs. These could come from substitution by nuclear power, for instance, which would involve health and other types of risks, by hydroelectric power with attendant externalities to river ecosystems, or by biomass from sinks based on monoculture with consequent ecological impacts. Another example would be a switch to diesel for transportation fuel, which would have a lower carbon content than gasoline but would have greater emissions of some conventional pollutants.

Also, if greenhouse abatement policies lead to substitution from electricity to more home fuel use, this could have important ancillary costs in terms of indoor air pollution particularly in developing countries where delays in electrification can also mean delays in attainment of literacy.

A further potential source of ancillary costs is the "ancillary leakage effect." Though there is debate about the significance of the effect, it is widely observed in modelling the impacts of Annex I actions to reduce GHG emissions that carbon emissions in non-Annex I countries may rise, due to changes in relative factor prices. The resulting increase in coal use (and in use of other fossil fuels) in non-Annex I countries—the carbon leakage—brings with it an ancillary cost of greater air pollution and other negative externalities. Because control efficiencies of conventional pollutants are lower in developing countries than in developed countries, and, perhaps, population densities near power plants and other large users of energy may be larger in developing countries, ancillary costs may be larger than suggested by carbon leakage or fuel use changes (Wiener, 1995). Preliminary analysis of extant modelling results suggests the possibility of ancillary costs resulting from increases in conventional pollutants in developing country regions as a consequence of "leakage effect" of carbon reductions under the Kyoto Protocol (Krupnick, Burtraw, and Markandya, 2000) However, the issue is not well-studied and the significance of the effect is not known.

Finally, Lutter and Shogren (1999) point out that ancillary costs could arise from the geographical reallocation of economic activity following a carbon mitigation policy. If carbon trading were in place, for instance, some areas, relative to their carbon allocation baseline, would be net sellers, others net buyers. In extreme cases, some net buyers could actually exceed their BAU carbon and conventional pollutant levels. Such cases may be far fetched. However, the possibility exists that net carbon permit buyers have facilities in or near dense, urban areas, while net sellers do not. In this case, net population exposures to ancillary pollutants could increase, even with constant aggregate carbon emissions.

It is interesting to note that the examples of ancillary costs given above relate to 'macroeconomic' policy options rather than 'micro' decisions where specific investment decisions consider technologies to limit or eliminate greenhouse gas emissions. Although ancillary costs could also arise at this 'micro' decision level, they are less likely to be as significant. This underscores the point that the kinds of ancillary costs and benefits considered depend on the policies and technologies being evaluated, local and regional demographic characteristics, and their specific national and institutional context.

2.4.4 Alternatives to economic valuation

Much of the controversy around ancillary effects really concerns the issue of valuation, especially how risks to human health and loss of life are valued (see Davis, Krupnick, and Thurston 2000 in this volume). This issue is one which has been the subject of considerable discussion in the literature for many years (Grubb, 1999). However, there is no inherent need for ancillary effects analysis to engage in valuation per se. Rather, this analytic decision is one of trade-offs. On the one hand, the valuation of ancillary impacts conceptually takes place according to public preferences for the different types of impacts. Many would think that this approach is better than having decision-makers substitute their own preferences for the public's. Such valuation permits social benefits to be compared to social costs of mitigation. On the other hand, valuation is highly controversial, with much uncertainty that is not always reflected in valuation analysis. Decision-makers routinely take actions that weigh economic and other impacts, including health impacts, against each other. Attempting to value these may sometimes obscure, rather than make more transparent, the decisions that are being made. This is both in terms of final decisions, and in engaging other players in the decision-making process.

An example of a relevant study outside the benefit-cost framework is a study of options to achieve greenhouse and air quality benefits simultaneously in four case study areas by STAPPA/ALAPCO (1999)[4]. Some of the main results are presented in Table 1. The STAPPA/ALAPCO case studies focused on the potential greenhouse and conventional pollutant reductions that could occur in four U.S. sample areas if harmonised strategies, defined as those strategies that simultaneously reduce conventional pollutants and greenhouse pollutants, were implemented. The areas differed in emissions, economic and energy profiles, making the reductions only broadly comparable. Here, no valuation is used, and air quality decision-makers can readily see the implications for emissions of climate change policy options. Similarly, some analysts and decision-makers may be inherently more comfortable with analysis which deals with human health and mortality impacts without valuing in monetary terms (see, for example, Working Group on Fossil Fuels, 1997, which estimated that the range of avoidable deaths that could occur globally by 2020 under some GHG mitigation policies extended from 4 to 11 million.)

Table 1. **Percent Reduction from Baseline Emissions in Four Case Study Areas, due to implementation of a package of climate change abatement measures**

Area	**SO_2**	**NO_x**	**PM**	**VOC**	**CO**	**CO_2**
New Hampshire	41%	17%	12%	3%	4%	12%
Atlanta, GA	40%	6%	1%	3%	4%	7%
Louisville, KY	26%	14%	3%	3%	4%	15%
Ventura County, CA	2%	4%	1%	4%	4%	11%

Source: STAPPA/ALAPCO 1999.

While of some value to decision makers, these types of estimates are not easily compared without a framework for assessing their economic impact and the efficiency with which various proposed targets and GHG reductions can be achieved. Participants at the workshop raised the option of performing cost-effectiveness analysis of alternative policies instead of cost-benefit analysis as a way to improve policy-making while avoiding the controversies and uncertainties of valuation.

2.4.5 Location of polluting activity

This is most obviously important in the case of air pollution. The social costing literature has vividly demonstrated that the benefits of emission reductions can vary tremendously depending on the spatial location of emission reductions vis-a-vis the proximity of the exposed population. Krupnick and Burtraw (1997) and earlier studies reconciling U.S. and European estimates for the social costs of fuel

4 The executive summary of the STAPPA/ALAPCO study is also reproduced in this volume.

cycles found that population density differences between Europe and the U.S. account for 2 to 3 times larger benefit estimates in Europe. Meteorology and other factors, including the potential for a non-linear relationship between emissions and pollutant concentrations, or between concentrations and health effects, further enhance the value of complex, location-specific models.

Pollution crosses over boundaries separating economies and societies that have different institutions, wealth and culture. This is particularly an issue in Europe, where transboundary pollution is an important element of regional policy making. ExternE work (EC 1995) pointed out that the externalities of energy use would be greater if it were not assumed that all pollution stopped travelling as soon as it reached the EU border. One of the explanations given for the lower estimated values of ancillary effects in the US relative to Europe is that more US pollution falls into the ocean where it has no health impacts. In fact, some of this pollution travels to Canada and estimates would be higher if these transboundary effects were included.

Ancillary impacts, such as changes in noise and ecosystem impacts also vary geographically. Even issues such as employment impacts will vary depending on the location of the effect.

2.4.6 Uncertainty

There is general agreement that the uncertainty surrounding the estimates of ancillary impacts is at least as great relative to the value of those estimates as that associated with other mitigation costs. The process by which external costs and benefits are calculated involve a number of physical modelling steps and a valuation step. The modelling involves estimation of emissions, their dispersion and transformation, and the impacts of the pollutants. The valuation of the impacts is based on statistical techniques that also have large error bounds. Each of the steps also has some uncertainty associated with it in terms of modelling choices. And the cumulative uncertainty, which is a combination of model and statistical uncertainty, could be quite large.

A good study of ancillary costs and benefits will provide some idea of how large the statistical uncertainty bounds are. A single number is indicative of a misleading approach and of less than thorough analysis. There is more than one way to report the uncertainty. For the statistical uncertainties, it is possible to derive probability intervals, using Monte Carlo methods, or by other statistical methods. For model uncertainty, other methods such as bounding analysis, breakeven analysis or meta analyses have been used. Finally a method that integrates both types of uncertainty based on subjective and objective error estimates is that of Rabl and Spadaro (1998). This method provides a quantification of the uncertainty and, recognising that many studies do not have enough information to carry out a quantitative analysis, reports a subjective qualitative indicator of uncertainty. For climate change work, Rabl and Spadaro (forthcoming) suggest that model uncertainty be described as follows:

- “Well Established”: models incorporate known processes; observations consistent with the models; multiple lines of evidence support the cost assessment.

- “Well posed debate”: different model representations account for different aspects of observation/evidence, or incorporate different aspects of key processes, leading to different answers. Large bodies of evidence support a number of competing explanations.

- “Fair”: models incorporate most known processes, although some parameterisations may not be tested representations; observations are somewhat inconsistent and incomplete.

Current empirical estimates are well founded, but the possibility of changes in governing processes is considerable. Possibly only a few lines of evidence support the evaluations.

– "Speculative": conceptually plausible ideas that have not received much attention in the literature or that are laced with difficult to reduce uncertainties.

At the least, ancillary benefit studies should provide similar qualitative information about uncertainty. In doing so, however, it is important not to overstate uncertainties, or to let "the perfect be the enemy of the good." Policy analysis of any importance always deals with considerable uncertainty, and judgements must be made as to the value of analytic resources relative to value of more certainty.

2.5 Use of modelling for ancillary effects analysis

Because of the underlying complexities of specific industry and geographic factors, disaggregated models represent a superior approach for developing accurate estimates of ancillary effects (again, including the monetization of physical effects). Aggregate models, which have many advantages for the study of GHG mitigation policies, are not well suited to capture the important detail or non-linearities involved in estimating ancillary effects.

There has generally been a lack of interface between large scale economic modellers and ancillary effects experts. The clear advantage of large-scale economic models is their ability to incorporate general equilibrium effects not available in the simpler models. In contrast, the disaggregated models have the capacity to generate geographic-specific results.

Debate over the appropriateness of large-scale versus disaggregated models has been an issue in climate change policy-making for many years. While there has been progress in bringing the two approaches together analytically, comprehensive ancillary effects analysis appears to require more detailed disaggregation. Therefore, in looking at methodologies to improve analysis of ancillary effects, attention to the development of models will be required. As well as more aggregate detail, these models will need to explicitly handle a range of emissions and environmental impacts, alternative approaches to environmental (and other) policies, and model the linkages between climate change policies, other policies, and economic and institutional factors (including technological change).

3. Categories of ancillary effects

Ancillary effects are most commonly thought of as "direct" changes in outcomes, most commonly health, ecological, economic/welfare, and, perhaps, congestion, and safety. However, in some cases, ancillary effects will be in the form of avoided costs, where the actual outcomes are the same, but the costs of achieving these outcomes is reduced. In terms of the types of climate policies examined, these have been almost exclusively *abatement* policies. However, it is almost inevitable that some level of climate change will already occur due to anthropogenic interference in the climate. Therefore, it is also worthwhile to consider ancillary effects of policies to *adapt* to climate change. Each of these issues is discussed briefly below.

3.1 Health

Most efforts to estimate ancillary effects of mitigation policies have focused on avoided deaths and illness tied with exposure to particulate matter in developed countries. Recent work indicates that there is a broader array of important air pollutants and associated health impacts, not all of which have been quantified at this time. Borja-Aburto et al, 2000 , provide meta-analyses on some of this recent work, finding increased mortality and morbidity associated with ozone and particulate matter. Table 2 indicates health effects that have been quantified, along with those that are not usually incorporated into such quantifications.

Table 2. **Scope of health effects**

Human Health Effects of Air Pollution	
Quantifiable Health Effects	**Non-quantified/Suspected Health Effects**
Mortality*	Neonatal and post-neonatal mortality
Bronchitis - chronic and acute	Neonatal and post-neonatal morbidity
Asthma attacks	New asthma cases
Respiratory hospital admissions	Fetus/child developmental effects
Cardiovascular hospital admissions	Non-bronchitis chronic respiratory diseases
Emergency room visits for asthma	Cancer (e.g., lung)
Lower respiratory illness	Behavioral effects (e.g.,.learning diabilities)
Upper respiratory illness	Neurological disorders
Shortness of breath	Respiratory cell damage
Respiratory symptoms	Decreased time to onset of angina
Minor restricted activity days	Morphological changes in the lung
All restricted activity days	Altered host defense mechanisms
Days of work loss	(e.g., increased susceptibility to respiratory infection)
Moderate or worse asthma status	Increased airway responsiveness to stimuli
	Exacerbation of allergies

Source: Adapted from: The Benefits and Costs of the Clean Air Act 1990 to 2010, U.S. EPA, EPA-410-R-99-001 1999).

The Workshop also considered that important interactions take place between poverty (or income, more generally), nutrition and pollutant exposure (Davis et al., 2000). Among the factors that may increase susceptibility to air pollution are:

1. enhanced susceptibility to pollution for populations with existing compromised health status, due to genetic predisposition, impaired nutritional status, or severity of underlying disease);
2. greater per capita exposures to atmospheric pollution in the center of cities than in the general population, due to greater pollutant density combined with a lower access to protective environments, such as air conditioning;
3. exposures to various residential risk co-factors such as indoor cooking fuels, rodents, cockroaches, dust mites, and other indoor pollution sources (e.g., gas stoves used for space heating purposes); and/or
4. increased prevalence of poverty, which is associated with reduced access to routine preventive health care, medication, and health insurance.

Most analyses of the ancillary effects of mitigation policies have looked at health effects associated with reductions in criteria (conventional) pollutants from energy combustion, including avoided deaths, acute and chronic illnesses, such as bronchitis, respiratory diseases and asthma, and behavioural effects, such as restricted activity days. There are other potentially important areas of health impacts, including occupational health and safety risks associated with, e.g. coal mining, forestry and the nuclear fuel cycle. In some cases, these risks may be wholly or partially internalised so that the ancillary effects of removing them may be less than expected.

Health effects typically account for 70-90% of the total value of ancillary benefits (Aunan *et al*, 2000, this volume) and so deserve special attention in ancillary effects analysis. The dominance of health impacts in ancillary effects analysis can qualitatively alter the analysis. Without better estimates of other impacts besides health, archaeological and ecological effects will generally not be relevant to decision-making on GHG mitigation.

The distribution of health effects between regions and among the population may differ. In places where the unemployment rate is high, the amount of Willingness To Pay (WTP)/Willingness To Accept (WTA) for avoiding such health impacts may be lower or the estimate of losses of earning due to illness may be lower[5]. The poor section of the population may suffer more than the rich as they have to spend higher proportion of their income on medical care. Such distributional impacts can be of great significance in assessing the ancillary health effects.

There are many complexities in valuing health impacts, and a very extensive literature on this topic, which is not reviewed here. It is notable, however, that the US EPA, in reviewing the evidence on this topic, identified a plausible range of $1.6 million - $8 million for the value of a statistical life, with a central estimate of $4.8 million (US EPA, 1999). This range is large, even when looking only at one country. In extending analyses across countries, further uncertainties are introduced. Davis, Krupnick, and Thurston (this volume) discuss the sensitivity of ancillary benefit estimates to assumptions about the mortality risk coefficient and the Value of a Statistical Life (VSL) Routine values used in the literature can lead to a difference of 300% in ancillary benefit estimates.

Given the importance of health effects to overall ancillary effects analysis, this level of uncertainty is important to how information is assessed. Three potential approaches to dealing with the prevalence and uncertainty of health impacts are:

- sensitivity analysis around plausible ranges. This is generally considered an important element of any analysis of complex issues;

- use of conservative estimates - for example relying on estimates which are the minimum acceptable estimates, perhaps based on direct health costs. While this approach should avoid arguments over the minimum level of ancillary effects, it may not be very helpful in determining optimal policy choices;

- avoiding valuation of health impacts - it may be that decision-makers are more comfortable with comparing health impacts directly with other impacts, including financial impacts, so that this approach could avoid considerable uncertainty while still assisting policy choice. However, this approach makes comparative and comprehensive analysis difficult and rules out normative policy analysis.

5 These terms are explained in the Appendix to Krupnick, Burtraw, and Markandya in this volume.

The state of the science of valuation of health effects is currently in ferment, with serious questions being raised about the inappropriateness of basing the valuation of mortality risks of the type affected by air pollution on labor market studies. *Ad hoc* adjustments for the shorter life span of those thought to be most affected by air pollution (the elderly and ill) have been made, but more credible estimates of the willingness to pay to avoid such impacts awaits new research. In developed countries, such efforts are more likely to lower such estimates relative to current estimates than raise them (see Davis, Krupnick, and Thurston, 2000, for a full discussion).

3.2 Ecological

Many experts believe that ancillary ecological benefits, though largely unstudied, may well be an important category of ancillary effects. Rothman (2000) indicates some of the areas where greenhouse policies could have significant ecological impacts (see Table 3). Climate change policy analysis often assesses land based abatement/sink policies as being more cost-effective than, for example, energy sector policies. This could be enhanced if there were significant positive ancillary effects of greenhouse policies in the energy sector. On the other hand, if there are significant negative ancillary effects, they could alter this analysis and lead to significant shifts in perceptions of relative costs of sectoral policies.

Table 3. **Policies and pressures**

	Pressure on Ecosystems				
GHG Policy	Harvesting	Waste residuals	Physical restructuring	Magnified Extreme Events	Exotic Species Introductions
Curtailment of Energy Use		+			
Changes in Energy Extraction and Production Methods		+	++		
Improvements in Energy Efficiency		++			
Fuel Switching	+	++	++		
GHG Capture		+	+		
Increase or Maintain the Area of Land in Forests		+	++		+
Manage Forests to Store More Carbon	+	+	++	+	+
Manage Non-Forested Lands to Store More Carbon	+	+	++	+	+
Reduce Dependence on Fossil Fuels Through Product Substitution	+		+		
+: potentially small effects; ++: potentially large effects					

Source: Rothman 2000.

Krupnick *et al* (1998) finds that airborne NO_x emissions slated to occur under the 1990 Clean Air Act significantly reduce nitrate loadings in the Chesapeake Bay. Aunan et al. (1998) suggests that forests in large parts of Europe are probably adversely affected by air pollution although, as they note, “the understanding of the causes and mechanisms is poor except in the most polluted areas where direct effects are plausible.” It is thus reasonable to assume that ecological ancillary benefits will arise from reductions in airborne emissions, although these have not yet been specifically modelled. A modelling effort recently established in Europe is beginning to look beyond airborne emissions and focus on direct water discharges associated with GHG policies (RIVM et al. 2000). Various types of both user and non-user benefits are likely to be tied with both air and water pollution, although, as indicated, they have not yet been specifically modelled as ancillary effects of GHG reduction policies.

Lack of available studies on ecological ancillary effects and land use impacts is an important gap in the knowledge base, as is indicated in the report from the Workshop regarding data gaps and research priorities.[6]

3.3 Other

The most commonly cited source of other ancillary effects are safety and congestion, both of which are especially important in transport. In the same paper in which he examined economic/welfare ancillary effects, Barker (1993) found that even a small tax increase would lead to a significant reduction in fatal and non-fatal road accidents. Sommer has recently extended this work (2000)[7] in several European countries, finding that the annual toll from air pollution associated with vehicles is equal to that linked with road injuries. Outside of transport, safety impacts could arise from shifts in the nature of production (e.g. shifting from coal mining to solar cell production) although the marginal impacts due to policies could be small and hard to measure. In such cases, it would be important to consider effects across all affected sectors, not just those where the safety impacts are in one direction.

Proost (2000) cites congestion as the overriding ancillary effect of transport in developed countries, outweighing even health impacts.. However, there is some question as to whether these effects are internalised already to transport users in the aggregate. If already internalised, ancillary effects would *not* be counted. Pearce (2000) also cites community severance as an ancillary impact related to transport, where roads divide ecosystems and social systems with consequent ecological and quality-of-life impacts.

Aunan et al. (2000), projected significant reductions in materials damage from implementation of energy efficiency programs in Hungary, and suggested significant increases in crop yields were likely to be obtained if NO_x and VOC emissions were reduced in large regions in Europe.

3.4 Equity

Social equity among different socio-economic groups remains of paramount concern to policy makers grappling with climate change. Concerns over relative regional impacts are also important, for example when governments consider impacts of carbon taxes on regional industries. But equity can also include a concept that different sectors of the economy should each bear a “burden” broadly equivalent to the share of emissions they cause, an effect noted by Bonney (2000). All of these equity impacts are fundamentally different from other ancillary effects. They relate to the distribution rather than the total share of costs and benefits. While this is clearly vital to policy-makers, it would broaden the scope of ancillary effects analysis far beyond what is manageable to include it. Equity issues warrant specific consideration in policy-making.

3.5 Economic

Economic ancillary effects can include a diverse range of issues. In some cases, it is questionable whether these effects may justifiably be labelled as ancillary effects of climate policies, and it is

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6 For more information on this see www.wri.org.

7 In this volume and original longer work, Kuenzli et al.,,Lancet, two weeks ago reference to be added…from Lancet web page?)

especially important here to distinguish primary and ancillary effects. For example, the energy cost savings that derive from a fuel efficiency policy are probably best seen as a direct financial benefit that should be offset against the costs of the policy. The most commonly discussed categories of economic effects are:

Ancillary financial impacts - These are financial impacts that are easily quantifiable, but do not derive directly from the policy put in place. They are often hard to distinguish from direct costs and benefits of a policy. So, with the energy efficiency example above, while fuel savings are best seen as a direct cost saving of the policy, changes to maintenance costs may be seen as an ancillary effect or may be simply added to the fuel savings costs. In the end, the key is to ensure all of these effects are included in the analysis somewhere. Examples include projected economic benefits of 0.05% of 1990 GDP from ancillary effects including road surface maintenance expenditures associated with implementation of an EU carbon tax (Barker 1993).[8] Such impacts can be very specific to the policy chosen, and so can be resource intensive to analyse and compare among policy options, especially as the ability to quantitatively examine these effects will vary.

Employment change - Climate policies clearly have potential to create or reduce jobs in a sector or geographic region. However, it is unclear whether these should generally be seen as ancillary effects. This is first because such impacts must really be looked at on an economy-wide basis - and in principle this should include an examination of the job impacts of raising money if the policy involves raising government funds. Also, in a fully employed economy, economic analysis indicates that much of the job impacts will be temporary, but there are still transitional costs. So, employment-related ancillary impacts are difficult to estimate as they require general equilibrium analysis at the same time as detailed sectoral and/or geographic analysis. Further, one must be wary of double-counting employment-related impacts and direct or general equilibrium costs. For this reason, most cost-benefit analyses include employment impacts under a discussion of distributional effects. As a minimum, inclusion of these effects should be detailed and transparent. On a pragmatic basis, it is noted that potential employment *losses* are routinely considered in policy-making, although not always in a transparent way, and not in the context of the flow-on effects of employment changes discussed above (under “ancillary costs”).

Energy security - Guaranteeing reliable, affordable energy has been an important objective of national governments since at least the first oil shocks, although the relative importance has declined in recent years. Most of the justification for concerns about energy security has stemmed from events outside the normal operation of markets, including cartel behaviour and war, making standard economic analysis difficult. ExternE work on this topic indicates it is likely to be of small magnitude relative to other effects. (European Commission 1998)

Induced technological change. Depending on policies proposed, induced technological change may or may not be an example of an ancillary effect. The important principle is consistency - if a policy redirects technological innovation, the losses as well as the gains must be included. There is a small but growing literature specifically focused on induced technological change, i.e., how much additional economy-wide innovation, if any, can be stimulated by GHG mitigation policies. However, there is no strong consensus of views in this evolving field (see, for example, Grubb et

8 There have been a number of studies indicating that, through appropriate recycling of carbon tax revenue, GDP can be increased through such a mechanism. Such results are the subject of considerable discussion in the literature and it is debatable whether these should be included as side effects of climate policies. From a pragmatic perspective, such impacts are *relatively* well-understood and evaluated and so do not need specific attention in the ancillary benefits framework.

al, 1995; Goulder and Schneider, 1999; and Goulder and Mathai, 1998). If GHG mitigation policies do accelerate the overall rate of technological change, then this would feed through to increases in GDP and competitiveness.

3.6 Avoided costs

Avoided costs refer to the cost savings that come from achieving a given outcome by introducing a climate change policy. So, the final health, ecological, or social outcomes are the same, but at a lower cost. The most commonly cited example is cost savings for meeting the SO_2 cap in the United States, as examined by Burtraw and Toman (1997), US EPA (1999), and Burtraw *et al* (1999). If the SO_2 cap is binding, moderate policies to reduce GHG emissions from the power and industrial sectors will not lead to further reductions of SO_2 emissions. Inasmuch as these emissions are capped, the result is abatement cost savings to those purchasing or otherwise acquiring SO_2 permits freed up by the GHG policy's induced SO_2 reductions. Burtraw *et al* (1999) estimate that these avoided costs could be equivalent to the direct ancillary benefits of a moderate greenhouse tax, therefore doubling the estimate of ancillary benefits (although this study also finds that such estimates are less than mitigation costs, significantly so for high carbon tax regimes). Avoided costs may also arise in other regulatory regimes, where companies have choices as to how to achieve a given environmental performance. The importance of avoided costs relative to direct ancillary effects is likely to grow over time, where reliance on cap and trade programs is expanded, or where negotiated settlements about how to meet ambient targets are used. Many previous ancillary effects analyses have failed to take into account these possible developments.

3.7 Adaptation

The IPCC Third Assessment Report distinguishes between responses to direct consequences of climate change, which are referred to as adaptation, and efforts to reduce or prevent these effects, which are termed mitigation. The Workshop did not concentrate on the former issue, beyond noting that adaptation to the effects of climate change generally receives less attention than mitigation in most countries' policy making processes. There is no denying that historical emissions have likely already made some climate change inevitable. Taking action to address vulnerability to these changes could provide ancillary benefits and costs.

For example, decisions to build sea walls or wildlife corridors as adaptation measures could lead to wider ecological positive or negative impacts. Preparations for the increased spread of disease could encourage improved general or specific medical care. Measures taken to increase irrigation efficiency in preparation for reduced availability of freshwater due to seawater intrusion could also benefit agricultur e and increase water for hydropower and drinking (see Scheraga 1999).

Given the relative scarcity of specific adaptation measures undertaken by countries, it is probably not worthwhile at this stage to consider ancillary effects analysis for these measures specifically. However, in developing any general approaches, it will be important to consider potential secondary or ancillary effects of adaptation policies.

4. Evidence from case studies

4.1 Ancillary public health benefits from GHG mitigation and comparison to mitigation costs

To assist with a systematic assessment of the impact on public health from GHG mitigation, Table 4 summarizes studies that have devised methods for estimating and valuing health impacts, including some studies presented at the Workshop. The table outlines the regions and scenarios assessed, the pollutant pathways and endpoints considered, , as well as the resulting estimatese of ancillary benefits in 1996$ per ton carbon. Table 5 shows the modelling methods employed in these studies and some basic characteristics of these assessments.

Burtraw and Toman (2000) (this volume), Kverndokk and Rosendahl (2000), and Ekins (1996) have all recently reviewed ancillary benefit studies finding that ancillary benefits can be from 30% to over 100% as large as gross (i.e., private) mitigation costs. For all of these studies, the benefits should be viewed as "very crude," because of use of simplistic tools and transfers of dose-response and valuation functions from studies done in other countries. For instance, some studies rely on expert judgement instead of established dose-response functions and estimates of national damages per ton rather than distinguishing where emissions changes occur and exposures are reduced. In these circumstances, large differences in ancillary effects per ton across several Norwegian studies can be attributed to differences in energy demand and energy substitution elasticities. If carbon-based energy production is reduced rather than switched to less carbon-intensive fuels, ancillary effects will be far larger. However, some studies did not consider the "bounceback" effect when a less carbon-intensive technology is substituted for a more intensive one in response to a carbon mitigation policy.

Kverndokk and Rosendahl (2000) have also assessed ancillary benefit studies that feed environmental benefits back into the economic model, and find that this modeling difference can significantly enhance estimated ancillary benefits. Recent work from the International Co-Benefits Program of the U.S. EPA, in conjunction with the governments of Chile, Brazil and China have produced some particularly useful results. They indicate that the adoption of readily available energy efficiency technologies in transportation, industry, and residential uses can provide a scale of ancillary effects equal to the costs of adoption of those GHG mitigating policies (see for example, Cifuentes et al., 2000).[9]

4.1.1 Summarizing the ancillary benefit estimates

The broad divergence in the value of ancillary effects estimates, even within the same country is evident in Table 4. Across countries, values range from around $2 to more than $500 per tonne of carbon abated, with the lowest estimates in the US and the highest in Chile and Norway. Where studies include uncertainty bounds, these are often quite large relative to the central estimate.

Figure 3 displays estimated ancillary effects per ton relative to the size of the carbon tax imposed (in $1996/tC). Points on the diagonal line AB=MC indicate equality between the two measures (because marginal costs (MC) will equal the tax rate in theory). Some points are on this line; more appear above it than below, with the studies on Norway and western Europe and the U.S. split. If abatement costs are assumed to be a square function of emission reductions, average costs can be computed as one half of marginal costs, with the corresponding diagonal line AB=AC. As more points appear

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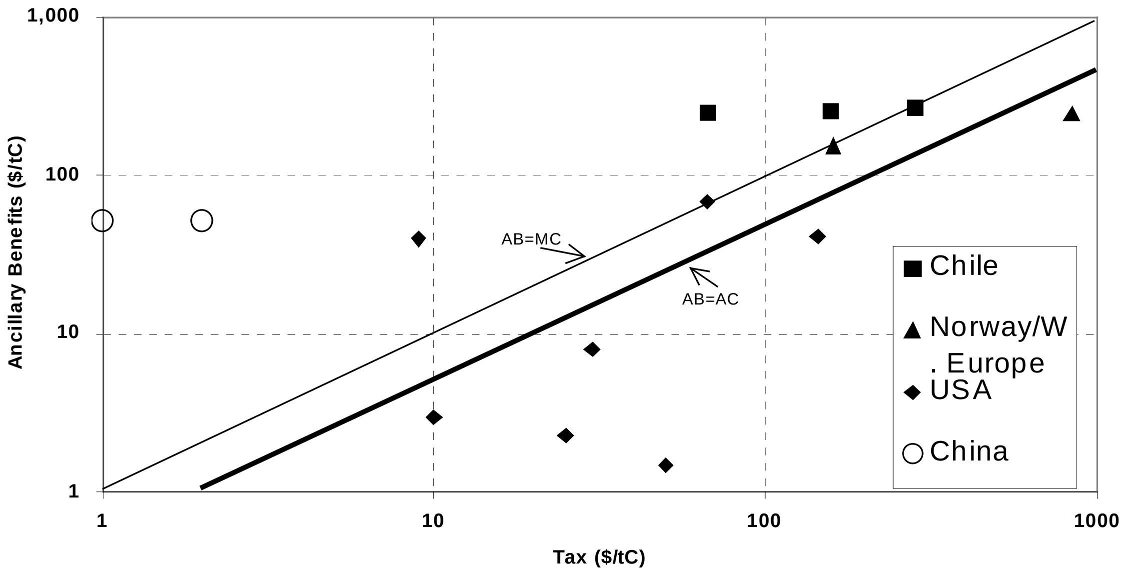
9 Cifuentes et. al. 2000 present results for Chile. Preliminary result from Brazil and Korea were also presented at the workshop - for more information see the website on the workshop: http://www.oecd.org/env/cc/

above the line than below, this indicates that ancillary benefits could be equal to or even exceed the costs of mitigation in some instances.

Figure 3. **Ancillary effects in 1996US$/tonC versus levels of the carbon tax**



Source: **authors**.

As for the change in ancillary benefits per ton C with a change in carbon taxes, there are differences in results. Burtraw et al (1999) show this ratio falling dramatically in percentage terms with higher carbon taxes[10], while Dessus and O'Connor (1999) show it rising slightly and Abt (1999) shows it rising dramatically. The Abt result arises because they assume that the proposed U.S. SO_2 cap becomes non-binding considerably below the higher tax rate modelled. In addition, the National Ambient Air Quality Standards are treated as a cap by Abt, with reductions in pollution below these "caps" treated as benefits but reductions above these caps treated as saving abatement costs.

It is not surprising that estimates of the size and scale of ancillary effects could and should diverge. This is because of differences in policy scenarios, modelling and parameters. In addition, there are real differences across countries, such as population size, regulatory differences, technological sophistication and baseline emissions of conventional pollutants. However, without a consistent methodological base against which to assess these matters, it is impossible to determine which of the differences in study results derive from "real" differences and which derive from alternative methods. Examining these studies against some of the issues identified in preceeding sections provides some clarification of these differences and of the relative role played by various components.

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10 Although it should be noted that this does not include consideration of avoided costs, which may be expected to rise relative to other types of ancillary benefits.

Table 4. **Scenarios and results of studies reviewed**

Study	**Area and Sectors**	**Scenarios** (1996 US$)	**Average Side effects $/tC** (1996US$)	**Key Pollutants**	**Major Endpoints**
Dessus and O'Connor, 1999	Chile (benefits in Santiago only)	1. Tax of $67 (10%C reduction) 2. Tax of $157 (20%) 3. Tax of $284 (30%)	1. $251 2. $254 3. $267	7 air pollutants	Health – morbidity and mortality, IQ (from lead reduction)
Cifuentes, et. al. 2000	Santiago, Chile	Energy efficiency	$62	SO_2, NO_x, CO, NMHC Indirect estimations for PM_{10} and resuspended dust	Health
Garbaccio, Ho, and Jorgenson, 2000	China – 29 sectors (4 energy)	1. Tax of $1/tC 2. Tax of $2/tC	1. $52 2. $52	PM_{10}, SO_2	Health
Wang and Smith, 1999	China – power and household sectors	1. Supply-side energy efficiency improvement, 2. Least-cost per unit global-warming -reduction fuel substitution, 3. Least-cost per unit human-air-pollution-exposure-reduction fuel substitution		PM, SO_2	Health
Aunan, Aaheim, Seip, 2000	Hungary	Energy Conservation Program	$508	TSP, SO_2, NO_x, CO, VOC, CO_2, CH_4, N_2O, VOC	Health effects; materials damage; vegetation damage
Brendemoen and Vennemo, 1994	Norway	Tax $840/tC	$246	SO_2, NO_x, CO, VOC, CO_2, CH_4, N_2O, Particulates	Indirect: Health costs; lost recreational value from lakes and forests; corrosion Direct: Traffic noise, road maintenance, congestion, accidents

Table 4 continued

Study	Area and Sectors	Scenarios (1996 US$)	Average Side effects $/tC (1996US$)	Key Pollutants	Major Endpoints
Barker and Rosendahl, 2000	Western Europe (19 regions)	Tax $161/tC	$153	SO_2, NO_x, PM_{10}	Human and animal health and welfare, materials, buildings and other physical capital, vegetation
Scheraga and Leary, 1993	US	$144/tC	$41	TSP, $PM_{10,}$ SO_x, NO_x, CO, VOC, CO_2, Pb	Health – morbidity and mortality
Boyd, Krutilla, Viscusi, 1995	US	$9/tC	$40	Pb, PM, SO_x, SO_4, O_3	Health, visibility
Abt, 1999	US	1. Tax $30/tC 2. Tax $67	1. 8 2. $68	Criteria pollutants	Health – mortality and illness; Visibility and household soiling (materials damage)
Burtraw et al., 1999	US	1. Tax $10/tC 2. Tax $25 3. Tax $50	1. $3 2. $2 3. $2	SO_2, NO_x	Health

4.1.2 Evaluation of the studies

Almost all the studies of ancillary effects reviewed here analyse the effects of a GHG reduction policy through a tax on carbon. The ranges of the tax extend from modest levels [9 yuan/tC in 2010 for Garbaccio et al. (2000), $10/tC for Burtraw et al (1999)] to high levels (254 $/tC Dessus and O'Connor (1999), $840/tC for Brendomoen (1994)). The US studies employ relatively modest taxes, between $10/tC up to $67/tC). Only two studies consider alternative programmes: Aunan 2000 considers a National Efficiency Programme, and Cifuentes et.al. 2000 considers energy efficiency improvements, based on the adoption of existing technologies. The level of abatement of these two studies is relatively modest. How do the different studies compare in terms of the issues identified above?

Baseline issues

Other policies – One of the key differences in study approaches relates to assumptions about baseline regulatory policies. For instance, Burtraw et al (1999) and Abt (1999) count the abatement cost savings from reducing SO_2 emissions in response to a carbon tax because SO_2 emissions are capped in the U.S. Similar adjustments are not made for SO_2 taxation (or taxation of other pollutants) in Europe, where large differences exist in regulatory policy.

Economic development - A major reason for differences in findings relates to whether the values for health impacts are increased with future income growth. Several of the developing country studies follow this approach. In general, developed country studies do not. This may create significant inconsistencies in comparisons of ancillary effects across countries. The U.S. Science Advisory Board has endorsed the idea of adjusting for economic growth. However, there is significant uncertainty concerning income elasticity of the willingness to pay for anticipated health improvements. A number of studies have found elasticities in the 0.2-0.6 range based on income differentials *within* a country. Such elasticities, when applied to transfers *among* countries, yield higher values than the default elasticity (1.0) used by most of the developing country-studies reported in Table 5.

Demography - None of the potential impacts of changing demographic profiles is explicitly incorporated into the ancillary effects literature, with the exception of Burtraw et al. (1999) which included population projections according to geography, age and income in their analysis.

Comprehensiveness of coverage – The major focus of all the studies is on changes in mortality associated with projected changes in particulate exposure, with differential handling of this issues (see below). Many studies did not go beyond particulate associated mortality, although a few included morbidity and there was a wide scattering of other issues covered in the other studies. Most studies did not include consideration of avoided costs, although Burtraw et al (1999) and Abt (1999) consider avoided costs due to the SO_2 cap.

Most of the studies rely on concentration-response functions from the health literature, and apply them using a standard methodology (Ostro 1996, US EPA 1999). The most important health effects are premature mortality and chronic respiratory effects.

Table 5. **Modeling choices of studies reviewed**

Study	Baseline (as of 2010)	Economic Modeling	Air Pollution Modeling	Valuation	Uncertainty treatment
Dessus and O'Connor, 1999	4.5%/yr economic growth; AEEI: 1% Energy consumption: 3.6% PM10: 1% Pb: 4.1% CO_2: 4.8%	Dynamic CGE	Assumed proportionality between emissions and ambient concentrations	Benefits transfer used: PPP of 80% U.S. VSL: $2.1 mil VCB: $0.2 mil IQ loss: $2500/point	Sensitivity tests on WTP and energy substitution elasticities
Cifuentes et al, 2000	For AP control, considers implementation of Santiago Decontamination Plan (1998-2011).	No economic modeling. Only measures with private, non-positive costs, considered	Two models for changes in PM concentrations. 1) Box model, which relates SO and CO to PM 2) Simple model assumes proportionality between PM concentrations apportioned to dust, SO , NO and primary PM emissions.; Models derived with Santiago-specific data and applied to nation	Benefits transfer from US values, using ratio of income/capita Uses original value for mortality decreased by 1 std. dev. VLS = $407k in 2000	Parameter uncertainty through Monte Carlo simulation. Reports center value and 95% CI
Garbaccio, Ho, and Jorgenson, 2000	1995-2040 5.9% annual GDP growth rate; carbon doubles in 15 years; PM10 grows at a bit more than 1% per year,	Dynamic CGE model; 29 sectors; Trend to U.S. energy/ consumption patterns; Labor perfectly mobile; Reduce other taxes; 2-tier economy explicit	Emissions/Concnetration coefficients from Lvovsky and Hughs; 3 stack heights	Valuation coefficients from Lvovsky and Hughs; VSL: $3.6 mil (1995) to 82,700 Yuan in 2010 (income elas =1). 5%/ year increase in VCB to $72,000	Sensitivity analysis
Wang and Smith, 1999		No economic modeling	Gaussian plume	Benefit transfer using PPP. VSL=$123.700, 1/24 of US value	

Table 5 continued

Study	Baseline (as of 2010)	Economic Modeling	Air Pollution Modeling	Valuation	Uncertainty treatment
Aunan, Asbjorn and Seip, 2000	Assumes status quo emissions scenario.	Two analyses: Bottom up approach and macroeconomic modeling	Assumed proportionality between emissions and concentrations	Benefit transfer of US and European values using 'relative income' = wage ratios of 0.16	Explicit consideration through Monte Carlo simulation. Reports center value and (low, high) (at which CL?)
Brendemoen and Vennemo, 1994	2025 rather than 2010. 2%/year economic growth, 1% increase in energy prices, 1-1.5% increase in electricity and fuel demand CO_2 grows 1.2% until yr 2000, and 2% thereafter	Dynamic CGE		Health costs of studies reviewed based on expert panel recommendations. Contingent valuation used for recreational values	Assume independent and uniform distributions
Barker and Rosendahl, 2000	SO_2, NO_x, PM_{10} expected to fall by about 71%, 46%, 11%) from 1994-2010	E3ME Econometric model for Europe		$/emissions coefficients by country from EXTERNE: 1,500 Euro/t NO_x for ozone; NO_x and SO_2 corefficients are about equivalent, ranging from about 2,000 E. to 16,000 E. per ton; PM_{10} effects are larger (2,000-25,000). Uses VSLY rather than VSL: 100,000 E (1990).	
Scheraga and Leary, 1993	1990-2010 7% growth rate C Range for criteria pollutants 1-7%/year	Dynamic CGE			

Table 5 continued

Study	Baseline (as of 2010)	Economic Modeling	Air Pollution Modeling	Valuation	Uncertainty treatment
Boyd, Krutilla, Viscusi, 1995		Static CGE		$/emissions coefficients	
ABT, 1990	2010 baseline scenarios – 2010 CAA baseline emission database for all sectors. Plus at least partial attainment of the new NAAQS is assumed. Benefits include getting closer to attainment of these standards for areas that wouldn't reach them otherwise. Includes NO_x SIP call	Static CGE		From Criteria Air Pollutant Modeling System (used in USEPA RIA and elsewhere)	SO_2 sensitivity – SO emissions may not go beyond Title IV requirements; NO sensitivity – NO SIP Call reductions not included in final SIP call rule
Burtraw et al, 1999	Incorporates SO_2 trading and NO_x SIP call in baseline;	Dynamic regionally-specific electricity sector simulation model with transmission constraints. The model calculates market equilibrium by season and time of day for three customer classes at the regional level, with power trading between regions.	NO_x and SO_2. Account for conversion of NO_x to nitrate particulates	Tracking and Analysis Framework: The numbers used to value these effects are similar to those used in recent Regulatory Impact Analysis by the USEPA.	Monte Carlo simulation for CRF and valuation stages.

All studies in Table 5 account for the best studied pollutant in the public health pathways—particulates. Most, however, do not consider secondary particulate formation from SO_2 and NO_x, or do so in a very simplistic manner. None of the studies of ancillary effects considered ozone-related morbidity or mortality. In a developed country, direct particulate emissions are likely to be a large fraction of particulate mass, making the lack of attention of secondary products less important. In developing countries, however, secondary products are likely to be far more important than primary particulates, and ozone can be quite important, especially in some meteorological zones. Omitting these products could bias ancillary benefit estimates downwards; using proportionality assumptions or other simple approaches raises uncertainties and may carry biases. Only one study considers lead emissions; few address ozone, which is widely acknowledged to increase morbidity, with much more uncertainty about its effect on mortality. The Abt study (1999) is the most comprehensive in its modelling of secondary particulate formation and dispersion, finding that 12 urban areas in the U.S. would come into compliance with the recently promulgated standard for $PM_{2.5}$ (*which has been remanded by the court and is not yet in effect*), for a carbon tax of $67 ($1996); otherwise these areas would not be able to meet the new standard. With there being little information on $PM_{2.5}$ concentrations in the U.S. urban areas; these estimates should be viewed as highly speculative.

Besides the differences of the base rate of the effects reflecting underlying age distribution, other factors account for the different outcomes of the studies. First, some studies use PM_{10}, while others use fine particles ($PM_{2.5}$), or even some components of them (sulphates and nitrates). When the individual components of $PM_{2.5}$ are used, their risk is assumed to be similar to that of $PM_{2.5}$. To date, this has not been verified (especially for nitrates, the secondary particulate product from NO_x emissions). Second, studies that look at age groups separately generally report higher impacts (Aunan et. Al, 2000) for example used a much steeper dose-response coefficient for people older than 65 yrs than used by other studies). Third, different studies consider different endpoints. This is especially important for mortality estimates. Most of the studies consider only associations with daily deaths, obtained from time-series studies. Very few (Abt, 1999, is one) consider the chronic effects on mortality, derived from cohort studies (e.g., Pope et al, 1995). Use of the latter effects can produce estimates of deaths that are three times larger than use of the former. Also, only a few studies consider effects on child mortality or morbidity.

A number of studies consider transportation-related consequences of a carbon tax. There are many significant issues in converting such changes to externalities, which are not addressed here.

None of the studies reviewed in this assessment reported estimates of ancillary costs.

Location – The level of spatial detail varies very widely, from the fine detail of Burtraw et al (1999) to national level evaluations including the international summation of national figures in Barker and Rosendahl (2000). Many studies extrapolate data from a single region or site to much broader coverage, while Dessus and O'Connor (1999) limit their analysis to the Santiago region. With the exception of the European assessments, none of the studies considers transboundary issues of ancillary impacts outside the study area.

Treatment of Uncertainty. Several of the studies use Monte Carlo simulation and other, less sophisticated techniques for characterising uncertainties. In addition, many conduct sensitivity analyses on key economic, health, and valuation parameters to estimate the range of possible ancillary effects.

Economic Modeling. Most of the studies in Table 5 use static or dynamic CGE models. One employs an econometric model which provides top-down and sectorally aggregate estimates of ancillary effects/costs (Barker et al, 2000). The modelling of carbon reductions as a result of a policy intervention, such as a tax, is credible though subject to key choices about energy substitution and demand elasticities. Although restricted to the electricity sector, the Burtraw et al (1999) model provides the sole example of location-specificity of an economic model. Because of its restricted focus, this analysis can provide more credible modelling of population exposure reductions than that generated from spatially aggregate models. Its detailed representation of investment choices along with the endogeneity of these choices also distinguishes this study and the model behind it. Finally, several studies do not use an economic model, but follow a bottom up approach, positing some increase in energy efficiency or reduction in carbon and estimating the ancillary effects that would result, at a reasonably detailed spatial level. Such studies suffer from not accounting for behavioral adjustments, such as energy substitutions, that could alter their estimates of ancillary effects considerably. The high ratio of ancillary effects to the carbon tax for Garbaccio, Ho, and Jorgenson (1999) assessment of China appears to be due to very optimistic assumptions about these elasticities.

4.1.3 Why studies for the same country differ

Clearly, studies can differ substantially in their treatment of many of the conceptual issues discussed above. Consider why the estimates of ancillary effects (costs) from two different studies of Chile differ. Dessus and O'Connor (1999) estimate benefits of about \$250/tC where as Cifuentes et al (1999) estimate benefits of about \$62/tC. Half of the Dessus and O'Connor benefits are tied with effects on IQ due to reduced lead exposure, an endpoint not considered by Cifuentes et al. The large lead-IQ effect is not consistent with US and European studies on this neurotoxic conventional air pollutant, but could in part be due to the relatively high exposures that currently occur in Chile.

Also, the VSL used by Dessus and O'Connor is more than twice as large as that used by Cifuentes (\$2.1 million vs. \$0.78 million). These choices were driven by alternative benefit transfer approaches. Dessus and O'Connor used 1992 (purchasing power parity) to transfer a US VSL, while Cifuentes et al used 1995 per capita income differences and the exchange rate. This comparison points out the importance of the choice of benefit transfer approach in estimating ancillary effects.

These differences aside, it appears that other modeling choices, which appear to be very different across the two studies, had little effect on the results. For instance, Dessus and O'Connor used a top-down model, while Cifuentes used a bottom-up approach.

For the US, Abt (1999) finds for a carbon tax of \$30, ancillary effects per ton are \$8. This includes mortality and moribidy. Burtraw et al (1999) find that for a \$25 carbon tax, the ancillary effects per ton are \$2.30. If avoided cost benefits of \$3 are added,[11] the difference in costs is not that large. For a \$50 per ton tax, Burtraw et.al. find ancillary effects of only \$1.50/tC, while for aslightly larger tax (\$67), Abt estimates that ancillary effects are \$68/tC. Why the large disparities here?

First, the Burtraw et al analysis uses mortality potency factors for NO_x (i.e., particulate nitrates) that are about one-third of those used by Abt and the factors used to value mortality risk reductions are about 35% lower in Burtraw et al (who adjust the VSL for the effects of pollution on older people rather than on averaged aged people). Second, Burtraw et al study is restricted to the electricity sector and is highly disaggregated and dynamic. The restriction to the electricity sector results in lower public health benefits than to the entire economy because, by 2010, NO_x emissions per unit carbon are projected to be lower for this sector than in the general US economy. Third, Abt finds that there are significant ancillary cost savings, i.e. the \$67 carbon tax is large enough to bring SO_2 emissions significantly under an SO_2 cap that is 60% lower than the current cap, and it brings NO_x emissions

[11] With a \$10 carbon tax, Burtraw et.al. (1999) find \$3/tC in ancillary benefits.

down low enough to bring significant numbers of non-attainment areas into attainment with the national ambient standards. It is unclear whether a $67 carbon tax would be large enough to promote such reductions.

In addition, Burtraw et al do not account for new, tighter ozone and PM standards being implemented in the U.S., but Abt does (while assuming only partial attainment of the standards). This baseline assumption should result in lower emissions of conventional pollutants to be controlled in the Abt study than in the Burtraw et al study and would in principle bring down the Abt estimates of ancillary benefits in comparison.

5. Impacts on policy making processes

The assessment of potential ancillary effects can influence choices about the stringency and types of GHG mitigation policies that may be adopted. . Depending upon the local, national and regional priorities, the understanding of potential ancillary effects can play a major role in affecting policy tools (e.g. taxes versus regulation versus voluntary agreements) as well as the sectoral, technological and geographic focus. Despite this importance, ancillary effects have not generally received systematic treatment in policy-making.

5.1 Ancillary effects and the policy "toolkit"

Climate change mitigation policy designed to comply with the Kyoto Protocol is still being developed in Annex I countries but the signs are that there will be a mix of economic, regulatory, voluntary and information instruments (OECD 1999b). There is a limited literature which considers how ancillary effects analysis affects the choice of policy instrument, with Pearce (2000) and Krupnick, Burtraw and Markandya (2000) providing some of the first comprehensive examinations of this issue.

Economic instruments (such as carbon taxes or tradable carbon quotas) have clear economic advantages over other environmental policies, and incorporating ancillary benefits/costs into such instruments is conceptually straightforward. By calculating the benefits, the level of a tax can be raised, or the allocation of quotas lowered to account for them.[12] However, incorporation of ancillary benefits alters a key advantage of economic instruments – the ability to allow abatement to take place wherever it is most cost-effective. Greenhouse gases affect the global climate in the same way regardless of their geographic source. Ancillary effects are, however, more localised, so that the location of GHG abatement affects the overall benefit achieved from a policy. Including ancillary effects in greenhouse policy design could mean geographically targeting GHG control, or spatially-differential taxation. In the case of emission trading regimes, it could lead to localised restrictions on carbon trades. So, consideration of ancillary effects can complicate "simple" economic instruments for GHG abatement at the national, regional or international level. It could, for example, affect the perceived optimal balance between domestic abatement and participation in international flexibility mechanisms.

Some regulatory approaches may lend themselves more readily to incorporation of ancillary effects. For example, standards based on Best Available Technology (BAT) could define 'best' technology as that which achieves not only some defined carbon emission target but also other associated targets. These targets could include many ecological and safety effects. Incorporation of ancillary effects will be more difficult in moving from BAT to 'practicable' or 'reasonable' technology standards, since

12 Or, in the case where there are net ancillary costs, the tax lowered or the quota raised.

increasing the range of incorporated effects will tend to make standards more environmentally stringent than such approaches would tend to support. Technology-based standards may also lead to higher costs in areas such as employment and induced innovation, as they can be more expensive than alternative approaches and/or redirect technology innovation away from more cost-effective opportunities.

"Voluntary" agreements between polluters and government are increasingly used in environmental policy (OECD 2000). These agreements can take a range of forms, but in general appear easily capable of incorporating ancillary effects, as the agreements are very flexible as to what parties wish to include in them. This can be done in ways that reflect very specific local circumstances, although increasing specificity will lead to increasing complexity and probably time for negotiation. As a minimum, agreements can ensure that approaches to one environmental problem do not lead to ancillary costs in relation to another.

Education/information programs seem superficially able to incorporate ancillary effects. Consumers can be presented with information about a range of impacts from product or service choices. However, for these programs to really incorporate ancillary effects, there would need to be some synthesis of information on the range of impacts. For example, adding a "greenhouse efficiency" rating to a dishwasher that already had ratings for energy efficiency, water consumption and recyclability, would add information but in a manner which required consumers to integrate across these pieces of information. This again would be similar in concept to adding a carbon tax to a range of environmental taxes. A single greenhouse rating adjusted for other impacts would be required for full incorporation of ancillary effects, and such an approach seems unlikely. Information programmes based on more qualitative information may be better suited to incorporation of ancillary effects.

Overall, inclusion of ancillary effects is likely to make *design* of GHG abatement policies more complex, especially in adding a geographic dimension which need not otherwise exist. In terms of *selecting* among policy instruments, different instruments do differ in their ability to incorporate ancillary effects. However, all instruments appear capable of building in ancillary effects to some degree. Other selection criteria of general economic efficiency, environmental effectiveness and equity, remain central to instrument selection.

5.2 Ancillary effects and sectoral policies

Inclusion of ancillary effects can affect not just the type of policy instrument put in place, but the sectoral targets of policies. Where policies are aimed at specific technologies, they may also affect the choice of technological options.

One obvious example is diesel fuel for transport. As a greenhouse measure, substitution of diesel for petrol can be a very cost-effective greenhouse abatement opportunity. However, when ancillary health impacts are included, the serious health costs of diesel make it look less attractive than other options (Pearce 2000).

However, in transport, the overall handling of ancillary effects is not so clear. Broadly, transport sector measures can be divided into those which reduce the overall level of traffic, and those which reduce emissions from a given level of traffic (such as alternative fuels or fuel efficiency). If health effects from air pollution are the overriding ancillary effect in the transport sector, then the two types of measures are both reasonably attractive. However, if, as Proost (2000) suggests, congestion is the overriding ancillary effect (at least in peak hours), then measures which reduce traffic will have far greater ancillary effects than those which reduce the emissions intensity of traffic. If this is the case, traffic-reducing measures can be preferred to others, even if they may appear less cost-effective from a greenhouse-only perspective. And such measures can be "no regrets" measures even when the costs are relatively high relative to the greenhouse abatement effect.

At a cross-sectoral level, it is commonly felt that measures such as reforestation or afforestation and land use change can be highly cost-effective greenhouse abatement options relative to measures taken in the energy sector. However, with evidence that 60% or more of the cost of energy sector measures can be offset by ancillary benefits, the relative cost-benefit assessment can change dramatically. In the case where ancillary benefits outweigh abatement costs, as found in some studies, the relative cost-assessment could be completely switched around unless there are comparable ancillary costs in non-energy sectors.

5.3 Ancillary effects and the policy making process

Clearly, governments sometimes take ancillary effects into account in policy-making related to climate change. One example is the decision by a number of countries not to allow any (more) nuclear power stations, and in some cases to support early shutdown of nuclear power stations, despite the fact that this may make achievement of greenhouse objectives more difficult. In these cases, the environmental costs of nuclear power are assessed as being greater than the potential greenhouse gas abatement benefits. Examination of support programs for diesel fuel is another common example. What is not clear is whether most policy processes have a *systematic* approach to consideration of ancillary effects.

5.3.1 Cost-benefit analysis

When well conducted, cost-benefit analysis (CBA) automatically accounts for ancillary benefits and costs, as it accounts for all "with" and "without" outcomes. So, more uniform use of this technique could be an important step toward extending policy analyses of potential GHG mitigation efforts. CBA is widely used for regulatory impact appraisal in the US, the European Commission now regularly subjects planned Directives to cost-benefit appraisals, and there is strong support for cost-benefit in the UK and Scandinavia. Other countries are known to experiment with cost-benefit analysis, but most decision-making is only partially informed by quantitative techniques generally, whether cost-benefit or some other technique.

There are a number of potential barriers to the wider use of cost-benefit analysis to incorporate ancillary effects in climate change decision-making, including:

- Complexities of the analysis, and disagreement over issues such as the valuation of human health impacts, make the CBA technique sometimes controversial. Given the potential importance of these valuations to ancillary impacts overall, differences in valuation techniques and results can lead to confusion for policy-makers.

- CBA is technically complex, involving appropriate selection of discounting rate, time horizon and the assessment and comparison of results; it requires considerable resources and skills, which may not always be in abundant supply.

- Cost-benefit analysis (and other formal guidance procedures) may be seen as a limit on policy-makers because it does not account for political conflicts (see, for example, Nyborg 1996 and EFTEC 1998).

- Institutional structures of decision-making within government militate against fully integrated policy making. For example, decision-makers on climate change are often at different levels of government, or in different Ministries, from those making decisions about local or regional air quality. Even within Ministries, there is often lack of co-ordination between policy-makers examining different issues.

- Health information is usually employed in CBA only when sufficient numbers of studies have been conducted on humans. This effectively makes proof of human harm the basis for analysis. More sophisticated use of experimental information and modelling simulations with respect to potential health impacts could reduce this problem.

So, while it is worthwhile to pursue wider use of CBA, in practice there will be limits on its use, thus it is important to consider other techniques that allow for consideration of ancillary effects in practice. CBA can never be fully comprehensive and in some cases may be very partial. In doing so, and considering the difficulties raised above, it is possible to divide alternative approaches into analytic issues (the first two points above) and institutional issues (the last two points).

5.3.2 Simpler analytic structures

The most important step in ensuring consideration of ancillary effects analysis is to ensure that the major sources of ancillary effects are identified. This paper identifies a classification of ancillary effects that could provide the basis for a checklist of effects. With more detailed consideration of case studies in a number of countries, more detailed checklists could be developed. These could be further developed through computer packages that identify likely ancillary effects of particular types of policies. A further refinement would be to include information, based on existing studies, of the likely magnitude of such benefits, and what factors affect the likely magnitude. In areas such as air pollution emissions and health impacts, there is considerable information in OECD countries which might be used to provide such a database. Such a database could have sufficient geographical diversity to allow for more detailed consideration of likely effects. However, in other areas such as ecological impacts, there would be very little existing information to draw on. Information outside OECD countries is also very sketchy.

Use of such checklists, even at a basic level, will help to ensure more systematic consideration of ancillary effects issues. A further step in complexity is to seek to quantify impacts in commensurate terms other than money. Multi-criteria analysis allows this to happen without formally having to monetise effects such as human health. However, it is not clear that using metrics other than money avoids any of the problems of monetisation, since weighting of different categories of impacts is still required. A hybrid form of analysis, in which some of the less controversial impacts are monetised and then compared with other major impacts, may provide a sufficient degree of analytic rigour and simplicity while allowing final decision-makers flexibility to consider tradeoffs. An effective dialogue between decision-makers and analysts would help the effectiveness of such an approach.

An alternative (or possibly complementary) approach is to develop improved analytic tools to handle ancillary effects analysis. This paper points out the weaknesses of many “top-down” models in including ancillary effects in the analysis of climate change policies. Work on improving the spatial detail of such models, and more specific handling of ancillary impacts, would greatly assist policy makers. Improved models could have endogenous links between climate policies, other policies, technological change and economic development (per Figure 2). However, the complexity of such approaches should not be underestimated and the ability of models to make great progress in this area in the short term will be limited.

5.3.3 Institutional approaches

Institutions for government decision-making are generally not conducive to the conduct of ancillary effects analysis. The tendency for Ministries to focus on a single set of issues, and even within Ministries for issues to be compartmentalised makes the consideration of impacts other than primary effects difficult. So, it is likely that institutional reform will be required, although not in drastic ways. Many governments are already taking steps in this direction. Given the comprehensiveness of greenhouse gas emissions throughout the economy, ancillary effects analysis offers an analytic construct which can support efforts toward more integrated decision-making.

An important element will be the provision of tools to assist analysts. As noted above, this could involve models, but could also be simple checklists that identify the most likely sources of ancillary effects, together with a mandate for their use to ensure at least qualitative treatment of ancillary effects. In developing a new Canadian action plan on greenhouse abatement, many sectoral committees were asked to identify the ancillary effects of potential measures, while a central "roll-up" group was given the task of integrating these different effects into a co-ordinated economic analysis. While the result was not consistent across all sectors, this central direction did result in somewhat more consistent approaches to examining ancillary impacts than previously[13]. More detailed guidance on possible ancillary effects could be helpful in eliciting more systematic attention to this issue.

Institutional steps to support ancillary effects analysis are similar to those required for environmental impact analysis (EIA). However, a key difference will be the need to allow for EIA of policies rather than of projects and the analysis may be required at an earlier stage in the decision-making process. Links between policy-EIA and ancillary effects analysis may be useful in developing common institutional approaches.

6. Conclusions and further steps

A number of studies have estimated the hypothetical ancillary effects of future climate change policies applied in particular countries or regions. Some studies find that the benefits of the health effects avoided by mitigation measures, per ton of carbon, are roughly equal to the carbon tax/ton needed to meet those goals or even exceed the tax. Others find relatively small ancillary benefits. Thus, it is difficult to generate broad, general estimates of the magnitude of ancillary effects relative to mitigation costs. The spread of results is due to methodological differences in these studies, gaps in the models and data used in these estimations, as well as "real" differences in economies and other factors across countries. However, there appears to be compelling evidence that ancillary benefits may be a significant fraction of or even larger than the mitigation costs, especially where baseline conditions involve relatively high levels of pollution and there are likely to be minor ancillary *costs.* This is true even in developed countries, where baseline conditions include long-standing regulatory programs and lower levels of pollution.

With respect to baseline considerations most of the literature on ancillary effects fails to systematically consider future government policies and regulations with respect to environmental policies. Other regulatory policy baseline issues, such as those relating to energy, transportation, and health, have been generally ignored, as have baseline issues that are not regulatory, such as those tied to technology, demography, and the natural resource base (Morgenstern, 2000). Adoption of more stringent regulatory regimes will result in significant reductions in potential size and scale of ancillary

13 The effects, if any, on final policy decisions, remains to be seen.

benefits. Where such regimes are not implemented, the potential for ancillary benefits can remain quite high.

The models most in use for ancillary benefit estimation – mostly CGE models – do a reasonable job estimating carbon reductions and mitigation costs from various policy interventions. But they also have the most difficulty in estimating such ancillary effects because they rarely have the necessary spatial, demographic or technological detail.

The studies reviewed here report that the biggest share of the ancillary effects is related to public health, but it is recognised that there are significant types of ancillary benefits or costs that have not been quantified or monetised, or even studied very carefully. The valuation of human health impacts is uncertain and crucial to determination of the relative importance of health and other ancillary effects. While there is a reasonable literature on this subject in developed countries, the developing country database is small.

In relation to policy choice, most studies are focused on the question of how ancillary effects analysis might affect the optimal level of policy response. Relatively little work has been done on how this issue affects the choice of specific policy tools or sectors for greenhouse gas abatement.

Further research would help to develop better understanding of ancillary benefits and costs, their magnitude and implications, especially in developing countries. At the same time, enough information is available to indicate that countries should include consideration of ancillary benefits and costs in their policy development if they are to promote cost-effective, integrated climate change policies.

In relation to further research, high priority areas for further research include:

- more targeted case studies on non-health ancillary effects, especially ecological impacts, some of which are related to air pollution;

- more comprehensive generation and use of health information on morbidity and mortality tied with the array of air pollutants of interest;

- more studies on the willingness to pay to reduce health risks, particularly in developing countries;

- more sophisticated assessments of baseline health and social conditions as these influence susceptibility to pollution in various regions;

- transparent and reasonable specification of regulatory baselines, particularly with respect to future air pollution regulation;

- development of indigenous data in developing countries, at least enough to assess how accurate benefit transfers from developed countries really are;

- development of integrated modelling, which allows simultaneous consideration of macro-scale and geographically specific impacts;

- better modelling to incorporate avoided costs, and integrated achievement of multiple policy goals;

- analyses that attempt to capture ancillary costs; and

– consideration of the time frame over which ancillary effects are realised: and the relationship to GHG policy timeframes.

In relation to incorporation in policy-making, the potential magnitude and impact of ancillary effects argues that ignoring them in climate policy making, especially at this relatively early stage can lead to important and costly errors. These could affect the level of response (including the balance between domestic response and international flexibility), the types of policy instrument used and the sectoral targeting of policies. There is no denying that the many uncertainties in ancillary effects analysis require a careful and transparent approach, including consideration of ancillary costs, if major policy mistakes are to be avoided. A "retreat to safe borders," where only the most certain information is included, could avoid these potential mistakes, but miss out on important insights. To avoid these problems, analytic transparency and better information is required.

In the short term, the methodological framework and summary of types of ancillary effects presented in this paper and in the proceedings volume provides a skeleton upon which countries can build their ancillary effects analysis. In many cases, specific data will be lacking, but reference to previous studies, with appropriate allowance for differences in methodologies and situations, will provide some indication of likely magnitudes of ancillary effects. An implicit assumption in economics is that it is better to make tradeoffs using public preferences (expressed in monetary units) than to use preferences of the decision-makers. While comparisons of non-economic impacts can result in loss of analytic rigour, they can make the analysis of ancillary effects less controversial and this can be of value to the policy process. Assessments of lives potentially saved or hospitalisations avoided, for example, can sometimes provide a more understandable context against which policy makers may consider their options, and can avoid the additional uncertainty from the valuation step. Many of the complexities involved in ancillary effects analysis are not subject to analytic resolution, nor are they likely to be resolved within most governments' resources.

Institutional reform will be especially important, including with respect to ensuring that critical information is gathered and monitored. Case studies of how different governments integrate ancillary effects into climate policy-making could be of benefit in identifying and assessing successful approaches. Centralised directives about appropriate methods and information to be gathered to ensure that ancillary effects are included in relevant policy-making will provide an important first step. In the longer-term, development of simplified, quantifiable methodologies for assessment will be required, especially with respect to impacts on land use, ecosystems, materials damage, archaeological resources, and other potential ancillary effects, for which there are no uniform methods of assessment available at this time.

In developing countries, there is far more uncertainty. The fact that these countries are not members of Annex I and have no current quantitative commitments under the Kyoto Protocol, allows more time for developing understanding of ancillary effects before policies are put in place. However, even here ancillary effects analysis can help countries who are potential recipients of CDM projects to assess which types of projects might lead to the greatest overall sustainable development benefits (WRI 1999).

The Workshop papers and the wider literature make clear that ancillary effects are potentially significant and warrant consideration in climate change policy-making. To date these effects are generally handled in an ad hoc, incomplete and/or inconsistent manner. The complexities involved are not to be underestimated, and there is scope for considerable further research and development to develop better methods and data for the systematic estimation of ancillary effects. This would help to ensure that ancillary effects are better integrated into policy development which in turn would improve greenhouse mitigation policies.

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