“Ancillary Benefits” of Greenhouse Gas Mitigation Policies

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Introduction

To a large extent, policies for limiting emissions of greenhouse gases (GHGs) have been analyzed in terms of their costs and potential for reducing the rate of increase in atmospheric concentrations of these gases. However, actions to slow atmospheric GHG accumulation could have a number of other impacts, such as a reduction in conventional environmental pollutants. The benefits (or costs) that result are often referred to as “ancillary” to the benefits and costs of GHG abatement (though there is controversy surrounding this terminology and the underlying concepts, as we discuss below).

A failure to adequately consider ancillary benefits and costs of GHG policy could lead to an inaccurate assessment of the overall impacts of mitigation policies. In particular, not accounting for ancillary benefits and costs would lead to an incorrect identification of a “no regrets” level of GHG mitigation. It also could lead to the choice of an unnecessarily expensive policy because of its failure to fully exploit potential ancillary benefits.

In this paper we first discuss in broad terms the concept of ancillary benefit. The concept turns out to be surprisingly difficult to define precisely. What is considered an ancillary benefit depends on the scope of policies being considered, the policy objectives being pursued, and the identity of the interests being served. That said, however, we describe what we believe is a serviceable definition of ancillary benefits from the perspective of evaluating GHG mitigation policies within the “Annex I” countries who would have emission limitation obligations under the Kyoto Protocol. We focus on mitigation in this paper, while acknowledging that adaptation policies also could have ancillary effects (for example, improved surveillance of tropical diseases could yield immediate health dividends; protection of coastal lands could harm wetland habitats in the more immediate term).

Having established a workable definition, we then turn to issues related to measuring ancillary benefits. To illustrate these issues, we consider how lower GHG levels resulting from less fossil fuel use could also reduce various “criteria” air pollutants (as defined in the U.S. Clean Air Act). Reductions in premature mortality from reduced exposure to various forms of air pollutants (mainly particulates) typically account for about 75-85 percent of *all* estimated benefits (not just health benefits) in economic assessments of improved air quality in the U.S. and other developed countries (see the reports by Lee et al. and the European Commission in Further Readings). Thus, focusing on this category of ancillary benefits is likely to provide a fairly reliable picture of total ancillary benefits, though controversy remains regarding the magnitudes of non-health effects.

Nevertheless, estimates of ancillary health benefits are quite variable. Ancillary benefits could offset a significant fraction of the costs of carbon reduction in some cases. They thus should figure prominently in estimating the overall costs and benefits of GHG policies. However, the considerable uncertainty about the size of ancillary benefits precludes identification of a single “best estimate” of their magnitude. And for a variety of reasons we explain below, we have much more confidence in more conservative estimates of ancillary benefits compared to estimates that equal or exceed the costs of GHG control.

What is an Ancillary Benefit or Cost?

An ancillary benefit of a GHG mitigation policy is understood by many analysts to refer to a benefit derived from GHG mitigation that is reaped in addition to the benefit targeted by the policy, which is reduction in the adverse impacts of global climate change. An ancillary cost would be a negative impact experienced in addition to the targeted benefit. The key elements of this definition, and the sources of much of the controversy surrounding the notion of ancillary, are “in addition” and “targeted.”

In the context we have used for defining ancillary benefits and costs, the principal policy goal is GHG mitigation in order to reduce adverse climate impacts. Asserting that ancillary benefits are additional to the benefits of reducing climate change does not mean these benefits are necessarily less important or that other policy goals are less important than addressing climate change. Benefits that are ancillary to climate change could be bigger in magnitude and more salient for the affected citizens and their decisionmakers. Our definition simply puts ancillary benefits in a certain policy context.

That policy context can be and is debated. Developing countries have argued with justification that they have more pressing immediate development and environmental needs compared to reducing their GHGs. This sentiment is reflected in the upcoming Third Assessment Report of the Intergovernmental Panel on Climate Change, which will put much emphasis on the notion of integrating climate change considerations into a broader “sustainable development” context (see the volume edited by Munasinghe and Swart in Further Readings). In this broader policy context, what we refer to as ancillary benefits could be considered as "co-benefits" of policies designed to promote various objectives. Whatever context is used, it needs to be clearly stated so that users of information about ancillary benefit and cost information can understand what is viewed to be the targeted effects of the policy in question and what is additional. Our own view is that when discussing climate change policies, the benefits and costs targeted by the policies should be considered as those associated with GHG mitigation and climate change risk reduction; other benefits and costs should be treated as ancillary in the sense we have defined the term above, but not given short shrift.

Some more specific but related considerations that arise in defining ancillary benefits and costs involve the scope of what is included in the calculation and the perspective of the decision maker evaluating benefits and costs. A number of kinds of impacts can be considered when evaluating ancillary benefits and costs. Much of the emphasis in these calculations has been on near-term health impacts in relatively close proximity to the GHG mitigation (for example, reduced incidence of lung disease in the same area as a coal-fired power plant if that plant is used less as a consequence of GHG mitigation measures). But a variety of other impacts also could be important.

Ecological systems could be affected by reductions in the flow of conventional pollutants (for example, less fossil fuel use could mean less nitrogen oxide deposition into water bodies). Reduced pollutants also could reduce some direct costs, such as maintenance of infrastructure and pollution-related reductions in crop yields. Traffic accidents could be reduced from less driving or slower traffic speeds. Reduced traffic could lower road maintenance costs. Increased forest areas could increase recreational opportunities and reduce erosion. GHG policies could also stimulate technical innovation.

Ancillary costs can arise if energy substitution leads to other health and environmental risks (from nuclear power, uncontrolled particulate emissions from biomass combustion, or use of diesel fuel in lieu of gasoline, since diesel fuel has lower carbon emissions but greater emissions of other pollutants). Better building insulation can add to indoor air pollution, including radon, and switching from coal to gas raises the specter of fugitive emissions of methane, a more potent greenhouse gas than CO_2. Policies that promote reforestation also could encourage destruction of old growth natural forests because younger forests allow more carbon storage. GHG mitigation policies could mainly redirect innovation efforts away from other productive activities, rather than increasing it. In addition, relatively expensive GHG mitigation policies could have some negative side effects on health by reducing the resources available to households for other health-improving investments.

An economic perspective on ancillary benefits and sees them as part of a larger concern with economic efficiency, as typically expressed in measures of aggregate benefits and costs. From this perspective, it is important not to isolate ancillary benefit and cost information from other relevant benefit and cost information associated with GHG policy. Ancillary benefits of a policy could be substantial, but they are nonetheless a questionable achievement if the cost of garnering these benefits is much larger. Often ancillary benefits are expressed in terms of a monetary measure per ton of carbon not emitted to the atmosphere as a consequence of the mitigation policy. Expressed this way, ancillary benefits (and costs) can be compared to the cost of mitigation. This is usually a meaningful and useful comparison, since ancillary benefits often (but not always) occur on the same relatively shorter-term time scale as mitigation costs, while the benefits of reducing climate change will be realized in the more distant future.

While the economic focus is largely on some aggregation of individual benefits and costs, it is important to recognize that as with any policy, some actors may benefit more than others and with ancillary costs there can be losers as well as winners. These distributional effects are not in themselves ancillary benefits and costs in the way benefits and costs are typically used in economic assessments of policies, since we lack any agreed-upon monetary metric for evaluating distributional impacts. Nonetheless, these effects are an important component of assessing the ancillary impacts of GHG policies and should receive careful consideration.

A final related point is that the scope and magnitude of ancillary benefits and costs depends on the perspective of the decision maker as to what constitutes policy relevant impacts. From the perspective of a hypothetical global decision maker concerned with global social well-being, ancillary benefits and costs are important wherever they are incurred. From this perspective it thus is important to consider how a redistribution in the location of GHG mitigation could affect ancillary benefits and costs.

In particular, policy mechanisms like international emissions trading or the Clean Development Mechanism (see the paper by Wiener) will redistribute ancillary impacts toward those countries undertaking more GHG mitigation. And efforts by Annex I alone to mitigate GHGs could have collateral effects in developing countries not bound by quantitative emissions limits, in that lower energy prices in international markets will stimulate some additional energy use and associated local environmental effects in those countries. On the other hand, for an Annex I decision maker evaluating the benefits and costs of GHG mitigation policies in his or her own jurisdiction, the relevant ancillary benefits and costs are likely to consist primarily of those affecting individuals in that political jurisdiction. Cross-boundary spillovers like those illustrated above are relevant for the Annex I decisionmaker only to the extent that a sense of ethical responsibility or altruism motivates a broader concern for the spillovers.

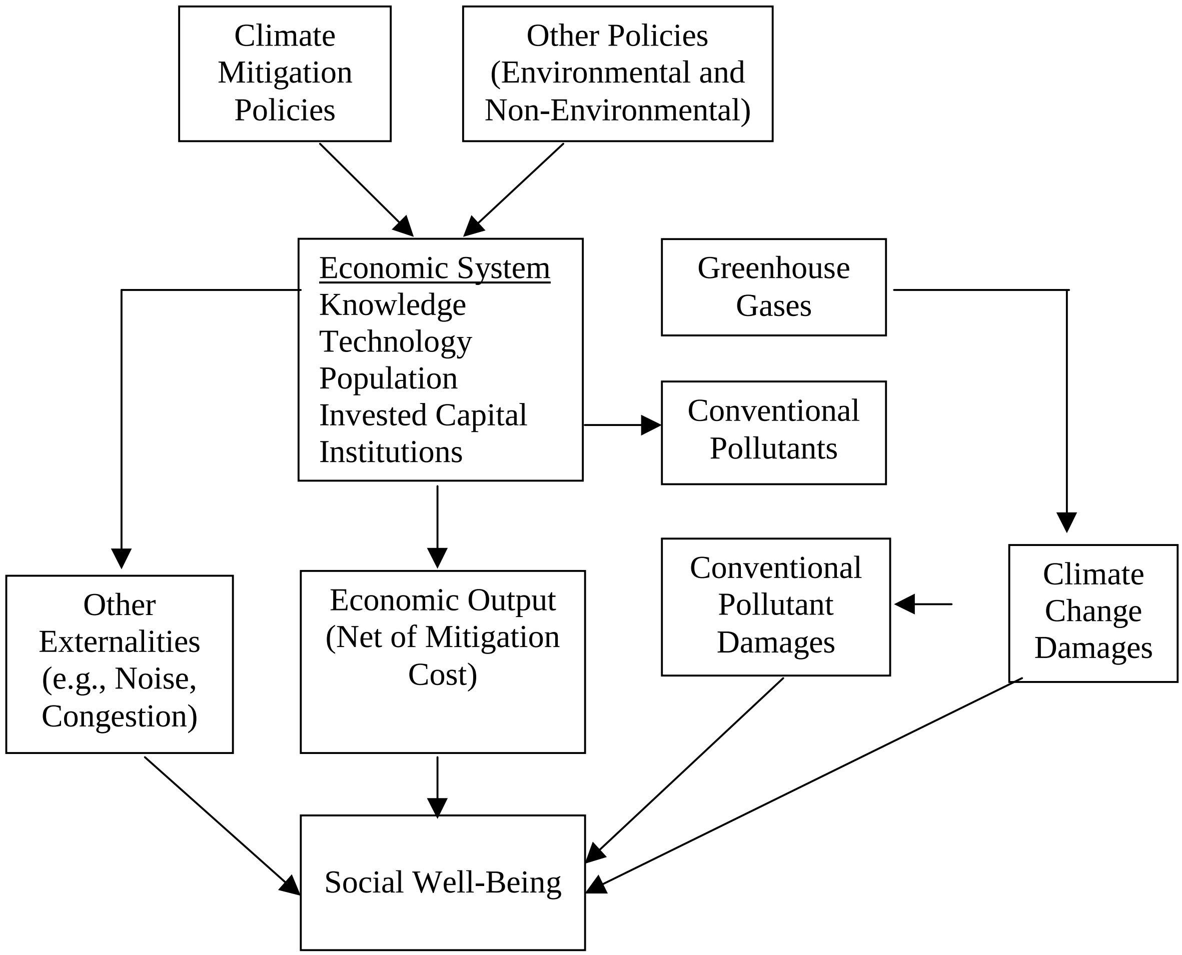
Still another perspective would be adopted by the developing country decisionmaker contemplating involvement in the Clean Development Mechanism. In this case, the primary benefits in terms of importance for the developing country considering hosting a GHG-reducing investment are likely to be the benefits that are ancillary to the GHG control according to our definition of the term.

Empirical Challenges in Assessing Ancillary Benefits and Costs

Having discussed some of the key conceptual issues surrounding ancillary benefits and costs, we turn next to some of the key problems in measuring these values. To do this, we make use of Figure 1. This diagram is a simple but useful illustration of how an “integrated assessment” framework can be used to describe links among climate and other policies, the economic system, health and environmental impacts, and social well-being (for another, simpler example of such an approach see the paper by Shogren and Toman). The diagram shows an economic system whose key elements are the population, endowments of other production inputs (capital), knowledge embodied in technology, and institutions. The overall output of this economic system is affected by the application of GHG mitigation policies and other policies (environmental and non-environmental). Specifically, these policies reduce standard economic output as reflected in mitigation costs; but the policies also reduce GHG emissions, other pollutants, and non-environmental impacts such as traffic congestion.

We can use this diagram to highlight some of the key challenges that arise in operationalizing this framework to develop empirical measures of ancillary benefits and costs. To calculate ancillary benefits and costs over time, one must compare two hypothetical situations. The first is a baseline scenario without any modification of GHG mitigation policy. This is sometimes referred to as “business as usual,” but this term is somewhat misleading since over time, the status quo can change even without modification of GHG policies. The baseline is compared to an even more hypothetical scenario that involves changing the current and future “state of the world” by modifying GHG mitigation. To carry out this exercise in practice means addressing a number of challenges.

Figure 1. A Schematic "Integrated Assessment" representation of GHG and conventional pollutant interrelationships.



How the baseline is defined crucially affects the magnitude of ancillary benefits and costs generated by a change in GHG mitigation policy. A recent paper by Morgenstern (see Further Readings) identifies a number of important influences on the baseline. One is the status of non-climate policies. This can be vividly illustrated with two environmental examples. Suppose that even in the absence of climate policy, conventional air pollutants are expected to drop sharply because of trends in policies for the regulation of conventional pollutants. (Note that such a trend requires not just tougher standards over time but also a maintenance or increase in the degree of compliance with those standards.) In this case, we would expect the incremental benefits from a reduction of conventional air pollutants in the wake of tougher GHG controls to be smaller than if the increased GHG controls were being applied to a dirtier baseline environment.

The second example involves the establishment of total emission caps for conventional pollutants, like the cap on sulfur dioxide (SO_2) from power plants in the U.S. If such a cap is imposed, then a stronger GHG mitigation policy will not have an effect on the total emissions of conventional pollutants unless a much tougher GHG policy is imposed, so tough that it leads to polluters reducing conventional emissions below the legal cap. What would be affected in less stringent cases is the *location* of the conventional emissions, and the total cost of meeting the conventional emissions cap will be lower since GHG policy will pay for achieving some of the conventional pollutant goal. But this example also illustrates the need for careful cost and benefit accounting when calculating ancillary benefits and costs.

Aside from the interaction of GHG policies and conventional pollutant policies over time, there are several other important elements in specifying the baseline. All the factors driving the evolution of the economic system are included in the list. The state of technology will affect the energy and emissions-intensity of economic activity. The size and location of the population, and the volume and location of total economic output, will affect both the scale of physical impacts on the environment and the risks posed to the population. Finally, the status of natural systems is also part of the baseline; it indicates the sensitivity of humans and ecological resources to changes in conventional pollutants.

Another important set of influences on estimates of ancillary benefits and costs include the scale of analysis, the level of aggregation, and the stringency of the GHG policy being considered. As discussed below, we find that estimates of ancillary health benefits from reduced conventional air pollutants (expressed as dollars per ton of carbon release avoided) tend to get smaller when the analysis shifts from an aggregate perspective to one that considers more carefully the effects of GHG policies on specific sectors at specific locations. These latter analyses appear better able to model the distribution of gains and losses, and the behavioral responses to GHG policies. As for the stringency of GHG policy, we would expect that a stronger GHG program will generate successively smaller increments in ancillary benefits and more ancillary costs as other risks decline relative to baseline levels.

The last point we raise in this section involves the assessment of the ancillary impacts themselves. In the area of conventional air pollutants and human health, which has received more research support than others, there nonetheless continues to be considerable uncertainty about how a change in ambient environmental conditions will affect health endpoints (for example, how many fewer cases of disease will result from somewhat cleaner air), and how much society values these changes. We illustrate the effects of these uncertainties below. The uncertainties are especially acute and troubling when one tries to use studies of impacts and valuations from developed countries to assess ancillary benefits in developing countries with lower incomes, different health status and infrastructure, and different cultural norms. Finally, other health and non-health ancillary environmental benefits and costs are even less researched or understood.

Illustration: Adverse Human Health Effects of Conventional Air Pollutants

An extensive scientific literature exists on the adverse human health effects of exposure to criteria air pollutants. These effects are widely seen as significant, though their size depends on the amount and duration of exposure to specific pollutants, and the nature of the exposed population, among other factors. The effects include the initiation or aggravation of various pulmonary disorders, as well as cardiovascular problems; they result in premature mortality as well as illness.

The pollutants described as particulates seem to have the greatest impact on public health, as already noted. These pollutants take a number of forms and arise from a number of sources. Particulates include soot emitted directly from the combustion process, soil dust (often mobilized in the air by human activities), and secondary pollutants such as sulfate and nitrate aerosols that form chemically in the atmosphere from sulfur dioxide (SO_2) and nitrogen oxides (NO_X). The various particulate substances are found in different proportions in different areas, and they have different degrees of impact on human health. Of the various types of particulates, sulfate and nitrate aerosols and their potency raise particular concern.

Another secondary pollutant that impairs human respiration is ozone (O_3), which is formed from the mixing of NO_X and volatile hydrocarbons (VOCs) in sunlight. While some short-term adverse health effects can arise from increases in O_3 concentrations (the magnitude of these effects continues to be debated), there is little evidence that ozone is associated with long-term illness or premature mortality for most of the population. Consequently O_3 receives much less weight than particulates in economic analysis. Carbon monoxide (CO), while obviously fatal at high concentrations, has much more limited health effects (primarily related to cardiovascular systems) at ambient exposure levels normally encountered. Moreover, CO emissions are decreasing over time as new vehicles with low emissions replace older vehicles.

While health effects predominate in assessments of environmental benefits from reduced emissions, there are other impacts. At high enough concentrations, criteria air pollutants can also damage ecosystems. NO_X and SO_2 are precursors to acidic deposition (commonly referred to as "acid rain") that has adverse effects on some forest species and aquatic wildlife. Atmospheric deposition of nitrogen also is a potentially significant contributor to damaging algae blooms in certain estuaries (e.g., the Chesapeake Bay in the U.S.). Both SO_2 and O_3 can damage the foliage of a number of crops and trees; O_3 is responsible for agricultural yield losses in the United States valued at several billion dollars each year, while the damages to forests and other ecosystems is still being assessed.

Criteria air pollutants also impair visibility and damage materials, affecting both aesthetic and property values. Airborne sulfur and nitrogen compounds, for example, tend to impair visibility, as do PM and ground–level O_3. PM soils buildings, statues, and monuments and acid rain accelerates their decay.

The vast majority of the U.S. economy's GHG emissions arise from fossil fuel combustion (see the paper by Darmstadter for details). Natural gas (methane) is the least carbon-intensive fossil fuel per unit of energy content. Methane also is a relatively "clean" fuel with respect to conventional pollutants. The main pollutants resulting from its combustion are relatively small amounts of NO_X. Petroleum products have intermediate carbon intensity and can generate significant emissions of PM, SO_2, NO_X, VOCs, and (in older cars) CO, again in the absence of effective emissions controls. Coal is the most carbon-intensive of the fossil fuels, and its combustion also generates relatively high emissions of criteria pollutants (especially SO_2, NO_X, and PM) in the absence of effective emissions controls. However, current regulatory standards require very stringent controls on gases, dust, and soot from stationary sources like power plants and these controls reduce emissions substantially.

The most likely sources of particulate reductions to be had from GHG policies that affect energy use are reduced emissions of SO_2 and NO_X that form sulfate and nitrate aerosols, and reduced soot from diesel engine emissions. Previous studies indicate that significant reductions in NO_X and CO are possible as a result of policies aimed primarily at reducing carbon emissions. Reductions in VOCs or direct particulate emissions from carbon policies may be much smaller than the NO_X and CO reductions, depending on the policies pursued. The actual extent of emissions reductions depends critically on both the type of fuel used and on the technologies employed for combusting fossil fuels and trapping pollutants in the waste gas stream.

Referring to our discussion in the previous section, there are a number of factors that will influence the size of ancillary human health benefits from GHG policies that also reduce conventional air pollutants. One important influence is the prospect of future tightening of pollution standards in the U.S., as reflected for example in proposed new air quality standards for ozone and particulates (which as of this writing are the subject of continued legal wrangling). Future air quality improvements will reduce the ancillary benefits actually achieved by climate policies compared to projections that fail to take into account future abatement measures for conventional pollutants. However, tighter standards with respect to conventional pollutants also are likely to raise the relative cost of using more carbon-intensive fuels. This means that tougher conventional standards will lower the opportunity costs of GHG emission reductions (for example, through fuel switching) in the future as well.

Another important interaction between GHG mitigation and conventional pollutant policies arises in considering the effects of GHG policies on U.S. SO_2 emissions. With the cap on SO_2 emissions from electric utilities in the United States, aggregate SO_2 emissions from electric utilities (the major source category in the country) are essentially independent of the amount of GHG emissions reductions, up to the point where SO_2 emissions became so small that the cap was not binding. This means that ancillary health benefits from SO_2 reductions as a consequence of small-to-moderate GHG initiatives will arise only from a spatial redistribution of SO_2 emissions, and these effects in turn are likely to be very modest. However, GHG policies could lower the cost of complying with the SO_2 cap by reducing the use of coal and thus the demand for SO_2 emission allowances.

More generally, the ancillary economic benefits of GHG emission reductions depend critically on geographic location. Differences in air quality imply different benefits from pollution mitigation. Population density also affects total benefits. For example, far more people are affected by emissions from a power plant located in New York than New Mexico. Failure to account for growth in population or migration that increase the number of exposed individuals leads to understatement of the ancillary benefits of GHG mitigation through reduction of conventional air pollutants.

A number of other factors discussed above in connection with baselines influence the scale of ancillary benefits. For example, continued technical innovation that improves energy efficiency and encourages the use of cleaner fuels will reduce baseline emissions and thus reduce ancillary benefits. Finally, the scale of ancillary benefits will depend on the scale of GHG mitigation – larger GHG mitigation should generate more ancillary benefits, though we would expect the incremental benefits to be decreasing as discussed above. (The possibility of increased health benefits as GHG controls became so strict as to drive SO_2 emissions below the current cap is a counterexample to this point.)

Table 1 summarizes a variety of ancillary benefit estimates, expressed in the common metric of dollars per ton reduction of carbon emissions. (References for the estimates are included in the "Further Readings" section at the end of this paper.) In every case the original studies that produced these data identified a wide range of possible estimates around the midpoint estimate for ancillary benefits per ton of carbon emission reduction that we report. Lower and upper bounds for each estimate vary from the midpoints by a factor of 2 to 10 or more.

Table 1 indicates a large variation even among the midpoint estimates in previous studies. A number of differences in the analyses help to explain the different results. These include differences in the modeling of criteria pollutant emissions reductions from GHG abatement, the estimation of health impacts from the criteria pollutant changes, and the evaluation of these impacts. One reason for the variation among studies is differences in the coverage of sectors, pollutants, and impacts. For example, one study considers a small voluntary program, while others consider the entire electricity sector or the economy as a whole. Some studies include a few of the larger health impacts, while others attempt a more comprehensive accounting of ancillary benefits.

Another important element here is the treatment (or lack thereof) of locational differences. More aggregated analyses calculate total emissions changes and apply a single unit value to value the avoided health impacts. In contrast, more disaggregated models can more precisely model the location of emissions, their transport through the atmosphere, and the exposure of affected populations. These analyses show that benefits do not have a simple proportional relationship to reduced emissions. Sensitivity analyses show that the abovementioned aspects are important influences on ancillary benefits, so the greater precision with which they are calculated in disaggregated models give us greater confidence in these results.

Moreover, longer-term future changes in pollution standards are not accounted for in any of the studies for assessing GHG policies that we discuss below (including our own). As a practical matter, this means our estimates of ancillary benefits should be considered more reliable for near-term GHG policies than for policies that are actually implemented in the 2008-2012 "commitment period" identified in the Kyoto Protocol. Other things equal (which in

Table 1: Comparisons of Estimates of Ancillary Benefits per ton of Carbon Reduction.

Source (explained in Further Readings)	**Targeted sectors, pollutants, and policy** (carbon taxes expressed in 1996 dollars, rounded to the nearest dollar)	**Average ancillary benefit per ton carbon reduction** (1996 dollars, rounded to the nearest dollar)
(1) HAIKU/ TAF	Nationwide carbon tax of $25 per ton carbon in electricity sector, analyzed at state level; only health effects from NO_x changes valued, including secondary particulates, excluding ozone effects. Range of estimates reflect with, and without, NO_x "SIP call" reductions included in baseline.	$2-$5
(2) ICF/ PREMIERE	Nationwide Motor Challenge voluntary program (industry), analyzed at regional level; only health effects from NO_x changes valued, including secondary particulates, excluding ozone effects.	$3
(3) Dowlatabadi et al./PREMIERE	Nationwide seasonal gas burn in place of coal, analyzed at regional level; health effects from NO_x changes valued using PREMIERE, including secondary nitrates, excluding ozone effects	$3
(4) EXMOD	Reduced utilization of existing coal steam plant at a suburban New York location; only PM, NO_x and SO_2 (under emission cap) changes valued (based on 1992 average emissions), including secondary particulates and ozone effects; all health, visibility and environmental effects that could be quantified are included.	$26
(5) Coal/PREMIERE	Equal percentage reduction in utilization of all existing (1994) coal plants in U.S. analyzed at state level; only health effects from NO_x changes valued, including secondary particulates and excluding ozone.	$8
(6) Coal/ PREMIERE/RIA	Equal percentage reduction in utilization of all existing (1994) coal plants in U.S. analyzed at state level; only NO_x related mortality changes valued, including secondary particulates and excluding ozone, using new EPA RIA estimates of impacts and valuations.	$26

Table 1 (continued)

Source (explained in Further Readings)	**Targeted sectors, pollutants, and policy** (carbon taxes expressed in 1996 dollars, rounded to the nearest dollar)	**Average ancillary benefit per ton carbon reduction** (1996 dollars, rounded to the nearest dollar)
(7) Abt/Pechan	Carbon taxes of $30 and $67 per ton carbon; modeled changes in conventional emissions and concentrations of particulates (no ozone) and changes in health status, visibility and materials damages. Estimates include avoided abatement costs for NO_x and SO_2. Attainment areas realize cost savings, nonattainment areas realize air quality improvements. All scenarios include NO_x "SIP call" reductions in baseline. Estimates estimates reflect outcomes with and without reductions in SO_2 below 1990 Clean Air Act, based on size of carbon tax (high tax leads to net SO_2 reductions) .	$8 and $68
(8) Goulder/ Scheraga and Leary	Economy-wide carbon tax of $144 per ton carbon with stabilization at 1990 levels in 2000; human health effects calculated from reduced total emissions of all criteria pollutants, no secondary particulates or ozone.	$32
(9) Boyd *et al.*	Economy-wide carbon tax of $9 per ton carbon; human health and visibility effects calculated from reduced total emissions of all criteria pollutants.	$39
(10) Viscusi *et al.*	Equal percentage reduction in utilization of existing (1980 average) coal steam plants nationwide; human health and visibility effects calculated from reduced total emissions of all criteria pollutants.	$86

practice is not the case), we would expect progress toward improved air quality in the U.S. to reduce ancillary benefits below the amounts shown in Table 1.

Treatment of the aggregate cap on SO_2 emissions created under Title IV of the 1990 Clean Air Act Amendments presents another important distinction among the studies. The avoided SO_2 abatement costs when emissions are lowered as a consequence of GHG policy likely are considerably smaller than the additional health benefit that would accrue if total SO_2 emissions were reduced below the cap. This aspect of ancillary benefits estimation is addressed in only a few of the studies in Table 1. Similar issues would emerge if EPA increased its use of economic incentive approaches, such as cap-and-trade regulation of NO_X to cut other pollutants.

Yet another factor is the uncertainty surrounding the economic valuation of avoided adverse impacts. For instance, one recent analysis (see the paper by Krupnick et al. in Further Readings) suggests that the value of reducing premature mortality, when considered in the context of reduction in conventional air pollutants, is significantly lower than the usual estimates applied in all of the studies reported here. On the other hand, there is some evidence of a stronger link between ozone concentrations and premature mortality then is represented in the existing studies considered here.

Firm conclusions are all but impossible to draw from the welter of estimates in Table 1, given the current state of knowledge. There is no "best estimate" of benefits per ton of carbon reduced for any particular GHG limitation, let alone for all possible GHG limitations.

As discussed in more detail below, however, we believe that modest but important ancillary benefits per ton of carbon emission reduction would result from a modest level of GHG control, and that the benefits might be more substantial in certain locations (those with denser populations and greater exposures to damaging criteria pollutants). The benefits per ton of carbon reduction would be larger with a greater degree of GHG control, though it is difficult to gauge by how much. Moreover, the literature provides little in the way of estimates for ancillary benefits other than those associated with the electricity sector. A more reliable and comprehensive set of estimates must await analysis of how GHG abatement policies would affect other emissions sources, among other advances in knowledge.

Having said this, if one's goal is to identify the ancillary benefit per ton of carbon reductions for a *modest* carbon abatement program, we have greater confidence in the first five estimates in Table 1, all of which reflect the impact of GHG reductions in the electricity sector. These estimates reflect the most detailed methodologies, including locational differences in emissions and exposures, and they take into account the role of the SO_2 cap in limiting ancillary benefits. Note that these estimates suggest modest (less than $10/ton) benefits on average for the United States as a whole, though benefits could be significantly higher in certain areas. The higher sixth estimate in the table reflects alternative assumptions about the scale of health impacts, the role of nitrates, and the economic valuation of impacts. The difference illustrates that ancillary benefits are sensitive to such assumptions, but given the controversy surrounding these specific assumptions, we put less stock in it.

However, the applicability of all these results is necessarily limited. Specific utility-sector policies for CO_2 reduction may have different effects in different geographic areas than assumed in these estimates, and may include changes not anticipated in the use of other technologies besides coal-fired plants. For example, an energy efficiency policy could reduce use of low-emitting gas as well. Moreover, health of course is not the only environmental benefit. GHG policies affecting other sectors – notably transportation – could also generate ancillary environmental benefits not captured in the utility sector analyses. Finally, benefits would be larger with non-marginal GHG mitigation policies, especially those that drive SO_2 emissions below the regulatory cap.

It may be tempting to embrace the last three studies in Table 1 that attempt to describe the effects of non-marginal, economy-wide GHG reductions and include a variety of pollutants and impacts. However, the methodologies in these studies simply compute a total economic benefit from a national reduction in criteria pollutant emissions. They lack attention to locational differences in emissions and exposures, and they inherently overestimate the total ancillary benefits from SO_2 reduction by failing to take into account the effect of the SO_2 cap. Moreover, the assessments and valuations of health impacts in these studies are based on literature from the 1980s, while the field has developed rapidly in recent years. Finally, the ancillary benefits from a comprehensive carbon tax may not reflect the benefits generated by other, less comprehensive and cost-effective policies.

Our focus in the foregoing discussion has been on ancillary benefit estimation in the U.S., as well as on health-based benefits. We conclude this section with some brief comments on studies for other countries. Some efforts at ancillary benefits estimation also have been undertaken for Europe, in particular the UK (see the papers by Ekins and Barker in Further Readings). These estimates tend to be much larger than even the larger U.S. figures. Several reasons seem to explain the difference. Population concentrations are higher in Europe than in the U.S., and wind patterns tend to direct more emissions over populated areas in Europe whereas more emissions are blown out over the Atlantic Ocean in the U.S. In addition, the studies include a range of ecological as well as health impacts, and the unit values used in these calculations tend to be substantial. The high valuation of ecological impacts (for example, acid precipitation damage to forests) could be attributed to a high European willingness to pay for ecological protection. On the other hand, there is reason to think the studies overestimate health benefits compared to the most recent literature on the subject. Moreover, many of the estimates accord substantial ancillary benefit to SO_2 and NO_X reduction that will already have taken place under new European regulations like the Second Sulphur Protocol. In other words, the studies reflect a misspecified regulatory baseline.

Ancillary benefits studies also are being undertaken for developing countries. This literature is beyond the scope of our paper; it will be reviewed in the forthcoming Third

Assessment Report of the IPCC. Speaking in general terms, developing country studies of ancillary benefits are limited in number and generate highly variable conclusions. The estimates are fraught with uncertainty, for several reasons. Detailed modeling of how emissions disperse in the atmosphere is rarely available, and detailed emission inventories are rare, so studies often have simply applied "unit values" expressing a change in health status resulting from a change in emissions without modeling emissions diffusion, population exposure, and health responses. Even when these intermediate steps are modeled, studies have used relationships from the US and elsewhere that may not be applicable because of other important influences on health status including differences in expected lifetimes and other risk factors. There is no doubt that lots of potential exists for health improvements in developing countries. There are uncertainties about how much GHG policy could contribute to this. There is also concern that GHG policy is not only an indirect way to achieve accomplish such goals, but potentially a more expensive way to do so than direct interventions in local environmental problems.

Lessons for Policy

As we noted at the outset, one important application of information about ancillary benefits and costs is in gauging the overall costs and benefits of GHG controls *given the presumed baseline conditions*; and in particular, to evaluate what degree of GHG mitigation might be "no regrets." The uncertainties plaguing current estimates of ancillary benefits make it impossible to confidently answer this question at this time. However, our analysis using RFF's HAIKU/TAF framework (which underlies the first row in Table 1) leads us to conclude that at least for relatively modest GHG control levels, ancillary benefits may be a significant fraction of costs. The marginal costs of small initial reductions are likely to be fairly low; indeed there is reason to think they would be close to zero (some would even argue less than zero, though we remain skeptical of this). As compared to such a low cost, ancillary environmental benefits of even \$3/ton of carbon reduced, let alone \$7-10/ton, could have a significant effect on the volume of no-regrets emissions reduction.

However, we emphasize there are large uncertainties in these estimates related to the measurement of health benefits, the valuation of those benefits, the magnitude of non-health benefits, and policies that will change baseline air quality and conventional pollutant control costs in the future. And our analysis and review of the literature does not lend support to the conclusion one finds in some other ancillary benefits studies that these benefits can offset much, all, or more than the cost of GHG abatement, especially for non-marginal GHG policies involving significant GHG controls.

Some insights can be derived from our analysis and applied to the design of policy, though they must be interpreted with care. Ancillary benefits may be larger for GHG policies that more heavily target coal use, but the reason has at least as much to do with the continued use of old, relatively polluting boilers as with the coal itself. And GHG abatement policies that have relatively greater effects and impose greater costs on newer plants will have the perverse effect of creating a new bias against construction of new facilities, resulting in continued use of older facilities and lower ancillary benefits.

GHG mitigation that occurs in areas especially conducive to the formation of secondary pollutants (ozone and secondary PM) will, compared with other options, confer larger ancillary benefits. Similarly, GHG mitigation that occurs at sources whose emissions affect large populations and ones that are subject to high levels of pollution also will tend to confer larger benefits than where populations are small and pollution is less.

The possible trend in ancillary benefits over time also is of interest. It is often argued that abatement costs associated with a goal like GHG emissions stabilization will rise over time because of growing energy demand, though technical progress and ultimately a transition to noncarbon backstop energy resources should ease the trend. The ancillary benefits of GHG control will rise over time as well, as a result of growth in population density and congestion as well as growth in income that can be expected to increase public willingness to pay for environmental protection. However, ancillary benefits will trend downward to the extent that more ambitious national goals for conventional pollutant control are set and achieved.

Last but not least, it is important to be cautious about the implications of ancillary benefits with regard to the desired level of GHG control. Put simply, when ancillary benefits are taken into account the GHG policies that have the lowest net cost to society do not necessarily target the least expensive sources for reducing carbon emissions. Nor do they necessarily maximize the ancillary benefits of GHG control. Ancillary benefits are important enough that they should be considered jointly with the costs of carbon reduction to identify the preferred policies for society. At the same time, the choice of policies can have important distributional effects, both in economic costs and ancillary benefits that must be considered as well. These distributional issues are an important topic for further research.

Further Readings

General (Technical) Readings

Barker, Terry and K.E. Rosendahl. 2000. "Ancillary Benefits of GHG Mitigation in Europe: SO_2, NO_X, and PM_{10} Reductions From Policies to Meet the Kyoto Targets Using the E3ME Model and EXTERNE Valuations." Paper presented at the IPCC Expert Workshop on Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation Policies, Washington DC, March 27-29.(*)

Burtraw, Dallas, Alan Krupnick, Erin Mansur, David Austin, and Deirdre Farrell. 1998. "The Costs and Benefits of Reducing Acid Rain," *Contemporary Economic Policy*, vol. 16 (October) 379-400.

Davis, Devra Lee. 1997. "Short-Term Improvements in Public Health from Global-Climate Policies on Fossil-Fuel Combustion: An Interim Report," *Lancet*, Vol 350, (November 8), 1341-1349.

Ekins, Paul. 1996. "How Large a Carbon Tax is Justified by the Secondary Benefits of CO_2 Abatement?" *Resource and Energy Economics,* vol. 18, pp. 161-187.

European Commission (EC). 1995. *Externalities of Energy: ExternE Project*. For the Directorate General XII. Prepared by Metroeconomica, CEPN, IER, Eyre Energy-Environment, ETSU, Ecole des Mines.

Krupnick, Alan J. and Dallas Burtraw. 1997. "The Social Costs of Electricity: Do the Numbers Add Up?," *Resources and Energy* vol. 18, no. 4 (December), pp. 467-490.

Krupnick, Alan, Dallas Burtraw and Anil Markandya. 2000. "The Ancillary Benefits and Costs of Climate Change Mitigation: A Conceptual Framework." Paper presented at the IPCC Expert Workshop on Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation Policies, Washington DC, March 27-29.(*)

Krupnick, Alan J., et al. 2000. "Mortality Risk Valuation in the Context of Air Pollution," forthcoming Resources for the Future Discussion Paper.

Lee, R., A. J. Krupnick, D. Burtraw, et al. 1995. *Estimating Externalities of Electric Fuel Cycles: Analytical Methods and Issues, and Estimating Externalities of Coal Fuel Cycles* (Washington, D.C.: McGraw-Hill/Utility Data Institute).

Morgenstern, Richard D. 2000. “Baseline Issues in the Estimation of the Ancillary Benefits of Greenhouse Gas Mitigation Policies.” Paper presented at the IPCC Expert Workshop on Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation Policies, Washington DC, March 27-29.(*)

Munasinghe, Mohan and Rob Swart, eds. 2000. *Climate Change and its Linkages with Development, Equity, and Sustainability* (Geneva, Intergovernmental Panel on Climate Change).

US Department of Energy. 1997. *Annual Energy Outlook 1997*.

US Environmental Protection Agency. 1996. *The Benefits and Costs of the Clean Air Act, 1970–1990*.

Table 1 source information

(1) HAIKU/TAF:

Burtraw, Dallas, Alan Krupnick, Karen Palmer, Anthony Paul, Mike Toman and Cary Bloyd. 1999. “Ancillary Benefits of Reduced Air Pollution in the US from Moderate Greenhouse Gas Mitigation Policies in the Electricity Sector,” Resources for the Future Discussion Paper 99-51 (September).

(2) ICF/PREMIERE:

Holmes, Rebecca, Doug Keinath, and Fran Sussman. 1995. "Ancillary Benefits of Mitigating Climate Change: Selected Actions from the Climate Change Action Plan," Final Report prepared for Adaptation Branch, Climate Change Division, Office of Policy, Planning and Evaluation, U.S. Environmental Protection Agency. Contract No. 68-W2-0018, ICF Incorporated, Washington, D.C., March 31. Results from this study were combined with analysis using the PREMIERE model cited below.

(3) Dowlatabadi et al./PREMIERE:

Dowlatabadi, Hadi, F. Ted Tschang, Stuart Siegel. 1993. “Estimating the Ancillary Benefits of Selected Carbon Dioxide Mitigation Strategies: Electricity Sector,” Prepared for the Climate Change Division, U.S. Environmental Protection Agency. August 5.

Results from this study were combined with analysis using the PREMIERE model cited below.

(4) EXMOD:

Rowe, Robert, et al. 1995. *The New York State Externalities Cost Study*, Hagler Bailly Consulting, Inc. (Dobbs Ferry, N.Y.: Oceana Publications).

(5) Coal/PREMIERE:

Palmer, Karen L., and Dallas Burtraw. 1997. "Electricity Restructuring and Regional Air Pollution," *Resources and Energy*, vol. 19, nos.1-2, (March), pp. 139-174.

Bloyd, Cary, et al. 1996. *Tracking and Analysis Framework (TAF) Model Documentation and User's Guide*, ANL/DIS/TM-36, Argonne National Laboratory (December).

(6) Coal/PREMIERE/RIA -- same as above, plus:

U.S. Environmental Protection Agency (USEPA). 1996. "Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard (Draft)," prepared by Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards, USEPA, Research Triangle Park, N.C. (December).

(7) Abt/Pechan:

Abt Associates and Pechan-Avanti Group. 1999. "Co-Control Benefits of greenhouse Gas Control Policies." Prepared for Office of Policy, U.S. Environmental Protection Agency (February).

(8) Goulder/Scheraga and Leary:

Goulder, Lawrence H. 1993. "Economy-Wide Emissions Impacts of Alternative Energy Tax Proposals," Draft Report submitted to Adaptation Branch, Climate Change Division, U.S. Environmental Protection Agency, (July).

Scheraga, Joel D., and Susan S. Herrod. 1993. "Assessment of the Reductions in Criteria Air Pollutant Emissions Associated with Potential CO2 Mitigation Strategies," Draft Report, Office of Policy, Planning and Evaluation, Climate Change Division, U.S. Environmental Protection Agency, Washington, D.C., (August).

Scheraga, Joel D., and Neil A. Leary. 1993. "Costs and Side Benefits of Using Energy Taxes to Mitigate Global Climate Change," *Proceedings 1993 National Tax Journal*, pp. 133-138.

(9) Boyd *et al.:*

Boyd, Roy, Kerry Krutilla, and W. Kip Viscusi. 1995. "Energy Taxation as a Policy Instrument to Reduce CO2 Emissions: A Net Benefit Analysis," *Journal of Environmental Economics and Management*, vol. 29, no. 1 (January), pp. 1-24.

(10) Viscusi *et al.:*

Viscusi, W. Kip, Wesley A. Magat, Alan Carlin, and Mark K. Dreyfus. 1994. "Environmentally Responsible Energy Pricing," *The Energy Journal* vol. 15, no. 2, pp. 23-42.