

BASELINE ISSUES IN THE ESTIMATION OF THE ANCILLARY BENEFITS OF GREENHOUSE GAS MITIGATION POLICIES

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Abstract

Greenhouse gas reduction policies which alter fossil fuel use can have near term environmental and social impacts quite distinct from the longer term benefits for climate change for which they were originally designed. The air pollution-related health improvements that accompany the reduction in GHGs are the best understood of these so-called ancillary or co-control benefits. Impacts on traffic congestion, ecosystem health, safety, and others are also potentially important, although to date they have been less well studied. Current estimates of the monetized health impacts associated with reductions in the use of carbon-intensive fuels range from \$3 to several hundred dollars per ton of carbon abated. Reductions in the costs of meeting existing pollution control requirements – so called avoided costs - can add to these benefits.

Some experts have questioned whether estimates of ancillary benefits are largely an artifact of the (unrealistic) assumptions used to generate them. It is argued, for example, that previously established environmental policies, technological, demographic, economic or other patterns already underway will improve those areas that some would count as ancillary to GHG reduction policies. If that were the case then there could be a significant problem of double counting in the estimation of ancillary benefits.

Without a credible and consistent specification of the health, environmental, economic or other conditions that occur in the absence of the contemplated policies it is not possible to estimate the true impact of such policies. To date, few studies have specified how the health, environmental or other ancillary benefits are expected to deviate from their current levels in the absence of GHG mitigation policies. Explicit and transparent specifications of the baseline conditions relevant to policy, technology, demography and other factors are crucial to the estimation of ancillary benefits.

This five-part paper catalogues and analyzes the broad set of baseline issues that must be addressed in order to conduct an informed policy debate on ancillary benefits. Following the Introductory Section, Section II provides background on some of the major types of ancillary benefits and reviews the literature on the health studies of air pollution. Section III develops a framework for considering baseline issues and identifies the critical baseline issues posed by current studies. Section IV provides a prescriptive checklist of key baseline issues. Section V offers a series of broad conclusions and, in the context of recent IPCC discussions, suggests that the expanded use of carefully done case studies offers the best means to estimate ancillary benefits at this time. Throughout the paper efforts are made to balance analytic robustness against the practicalities of policy analysis. As much needed information is missing and many data gaps exist, this paper also provides some preliminary guidance

with respect to research priorities that need to be addressed in order to improve the ability of the research community to assess the full range of ancillary benefits of GHG mitigation policies.

1. Introduction

It is now well established that greenhouse gas reduction policies, which create incentives to alter the uses of fossil fuels, can have near term environmental and social impacts quite distinct from the longer term benefits directly associated with climate change. The air pollution-related health improvements that accompany the reduction in GHGs are the best understood of these so-called ancillary or co-control benefits. Impacts on traffic congestion, ecosystem health, safety, and others are also potentially important, although to date they have been less well studied.

Current estimates of the monetized health impacts associated with reductions in the use of carbon intensive fuels range from \$3 to several hundred dollars per ton of carbon abated. Reductions in the costs of meeting existing pollution control requirements – so called avoided costs - can add to these benefits. Even the low and mid-range estimates could offset a significant portion of the projected GHG abatement costs and thereby add new meaning to the interpretation of ‘no regrets’ policies. Inadequate consideration of ancillary benefits could lead to the selection of inappropriate GHG mitigation policies because of the failure to capture the full range of benefits. However, many problems remain in developing credible numbers.

Some experts have questioned whether estimates of ancillary benefits are largely an artifact of the (unrealistic) assumptions used to generate them. It is argued, for example, that previously established environmental policies, technological, demographic, economic or other patterns already underway will improve those areas ancillary to the GHG reduction policies. If that were the case then there could be a significant problem of double counting in the estimation of ancillary benefits.

It is well known that without a credible and consistent specification of the health, environmental, economic or other conditions that occur in the absence of the contemplated policies it is not possible to estimate the true impact of such policies. For example, the baseline scenarios for greenhouse gases over the next one hundred years have been widely debated by the Intergovernmental Panel on Climate Change (IPCC, 1998). Strong views have been expressed that the draft IPCC baseline scenarios do not reflect the full range of plausible GHG emission futures. Errors in these baselines can bias estimates of the direct benefits and costs of GHG mitigation policies.

An important but less well-explored area concerns the baselines used for a host of ancillary benefits. To date, few ancillary benefit studies have developed counterfactual scenarios explicitly tailored to the ancillary issues. That is, they generally do not specify how the health, environmental or other ancillary benefits are expected to deviate from their current levels in the absence of GHG mitigation policies. For the same reason that understanding the baseline emissions of GHGs is essential to estimating the direct benefits and costs of mitigation, explicit and transparent specifications of the baseline conditions relevant to policy, technology, demography and other factors are crucial to the estimation of ancillary benefits.

The purpose of this paper is to catalogue and analyze the broad set of baseline issues that must be addressed in order to conduct an informed policy debate on ancillary benefits. Section II provides background on some of the major types of ancillary benefits and reviews the literature on the health studies of air pollution. The review includes papers from the U.S., Europe, and to a very limited extent, developing countries and economies in transition. While a number of the papers have been published in the peer-reviewed literature, some are sufficiently new that they are still circulating in

draft form. Section III develops a specific framework for considering baseline issues and identifies the types of baseline issues most likely to affect ancillary benefit estimates. Section IV provides a prescriptive checklist of key baseline issues. Section V presents the overall conclusions. Throughout this paper efforts are made to balance analytic robustness against the practicalities of policy analysis. As much needed information is missing and many data gaps exist, this paper also provides some preliminary guidance with respect to research priorities that need to be addressed in order to improve the ability of the research community to assess the full range of ancillary benefits of GHG mitigation policies.

2. The Nature and Types of Ancillary Benefits

2.1 Definitions

To shed light on the conceptual issues we begin by asking what do we mean by “ancillary benefit” of a GHG reduction policy? Stated simply, ancillary benefits (also known as secondary or co-control benefits) are those which accrue as a side effect of policies targeted at a particular problem. If such benefits legitimately depend on GHG reduction policies then they should be considered in the overall costs and benefits of the GHG policies. The inclusion of ancillary benefits in the overall mix of benefits associated with GHG reduction policies can affect both the optimal level of abatement as well as the particular policy instruments selected.

Not all ancillary benefits are positive. Negative ancillary benefits indicate a conflict between or among policy objectives. Particularly large negative ancillary benefits could even transform a worthwhile policy into one that is not worthwhile. Conflicts among policy objectives exist in a number of well-known areas relevant to GHG mitigation. For example, diesel vehicles (lower GHG, higher particulate emissions), natural gas fire co-generation in urban areas (lower GHG, higher urban NO_x), or non carbon based technologies like nuclear power or wind turbines (lower GHGs, but increases in other risks) all present particular risk-risk trade-offs. While none of these negative effects have been formally quantified in the ancillary benefits literature *per se*, the trade-offs they represent have been extensively studied elsewhere.

To determine the ancillary benefits (or costs) of a GHG policy, one must compare conditions in a world with the policy to conditions in a world without it. To produce such estimates, both the “with” and the “without” scenarios must be modeled; they cannot be observed. The quality of the information available to develop estimates of these scenarios is limited by three basic uncertainties:

- i. What economic actors (firms, households) in a particular country are doing at the present time with respect to air, water, waste, emissions, accidents, etc *independent of* any proposed GHG mitigation policies?
- ii. What these actors will do *in response to* the new GHG policies?
- iii. What these actors *would have done* in the future if the GHG policies had not been adopted?

The first of these items is, in principle, knowable *ex ante* but in practice is often not fully understood by policy makers. The second and third items are hypotheticals, based on economic and process-analysis models and, perhaps, qualitative information from industry or other experts.

Interestingly, even after implementing a policy it is not easy to determine the true benefits (costs) of the policy, since the world with the policy is observed, but the counterfactual is not. The *ex post* cost

estimate must deal with the same uncertain elements but from a more favorable position, especially on items (i) and (ii). It can be no worse than the *ex ante* estimate, because it has more information to draw on. What is still missing is information on item (iii), the counterfactual, although better information is usually available *ex post*. Thus, one observation is that the definition of ancillary benefits, like that of any other type of benefit (or cost), is somewhat arbitrary, depending as it does on the analysts' beliefs on what would have happened without the policy.

2.2 Categories

Acknowledging the somewhat arbitrary nature of estimates of ancillary benefits, however, does not diminish the importance of developing credible and consistent baselines. The most commonly discussed ancillary benefits are: health, ecological, economic/welfare, and safety. Other benefit categories, e.g., employment or technological change (both of which could lead to increases in GDP growth) or what Pearce (2000) refers to as community severance (loss of community due to increased traffic flows) may also be relevant.

2.2.1 Health

Health benefits, including both morbidity and mortality, are the most studied and represent, by far, the largest category of estimated ancillary benefits. They are considered in some detail in a later part of this section. The issues relevant to baselines *per se* are discussed in Section 3.

2.2.2 Ecological

Some experts believe that ancillary ecological benefits, though largely unstudied, may well be an important category of ancillary benefits. The deposition of air pollutants, including nitrogen compounds, is a potentially important category of ancillary ecological benefits. Reduced water discharge or changes in runoff and soil erosion are other possible categories. A paper by Krupnick *et al.* (1998) finds that airborne NO_x emission reductions slated to occur under the 1990 Clean Air Act significantly reduce nitrate loadings to the Chesapeake Bay. Although this study did not monetize the benefits of these reductions nor did it specifically tie them to carbon reduction policies, other work by some of the same authors has estimated ancillary health benefits associated with reduced NO_x emissions (Burtraw *et al.* (1999)). A paper by 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, although not yet specifically modeled, to presume that ecological benefits via reduced airborne emissions may be a significant source of ancillary benefits.

A modeling 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 plausible on both the air and the water side although, as indicated, they have not yet been specifically modeled as ancillary benefits of GHG reduction policies.

2.2.3 *Economic/Welfare*

Economic or welfare benefits are another potentially important category of ancillary benefits. To develop credible estimates of benefits in this area it is sometimes important to distinguish between the impacts on stocks vs flows as part of the methodological framework.

A paper by Barker (1993) examined the relationship between the proposed EU Carbon/Energy tax and a number of economic/welfare categories associated with transportation including road surface maintenance expenditures, traffic noise, and congestion. He estimated ancillary benefits in these categories associated with the proposed EU tax amounting to about .05 per cent of 1990 GDP. He noted that his estimates are likely to underestimate the total economic/welfare ancillary benefits from the categories examined because his model failed to capture a potentially important feedback namely, the reduction in air emissions associated with the resulting higher average driving speeds. Thus, a full specification of the transportation-related ancillary benefits would likely include some further health improvements. In a similar vein, a recent Australian paper examined how GHG mitigation policies including road pricing would reduce traffic congestion (Australian Bureau of Transport and Communication Economics, 1996).

Aunan *et al.* (1998), in their study of Hungary, explore the relationship between energy saving programs and reductions in materials damage. They also examine potential increases in crop yields associated with reductions in air pollution (ozone). The materials damage study is based on a detailed analysis of building mass and materials in Budapest, together with results from other studies in Europe. They find that the 6 per cent reduction in SO₂ concentrations associated with the implementation of the energy saving programs leads to annual reductions in materials damage on the order of \$30-35 million. As the authors note, however, the fact that SO₂ concentrations have declined over the past few years implies that their baseline assumptions (constant 1990 levels) are too pessimistic which, in turn, suggests that their damage estimates are likely overstated.

The Aunan *et al.* (1998) analysis of the relation between Hungary's energy saving programs and increased crop yields is more preliminary in nature. It is based on an estimated linear relationship between the yield of wheat and ozone concentrations, and on (the quite limited) information on the local atmospheric chemistry of ozone formation. They find that energy saving programs in Hungary are likely to have only modest effects on crop yields in that country. However, they suggest that significant increases in yields are likely to be obtained if NO_x and VOC emissions are reduced in large regions in Europe.

Gielen and Peters (1999) examined the effects of different levels of carbon taxation in Europe on waste management. Although they find little effect on total waste volume, they estimate significant changes in the mix of wastes. For example, they predict an increase in the share of paper and wood products. Further work needs to be done to understand the full economic implications of these effects on waste management (both positive and negative). Other candidate economic/welfare issues include the improved visibility and reduced materials damage likely to flow from GHG mitigation policies.

2.2.4 *Safety*

Safety represents a further area of interest for potential ancillary benefits. In the same paper in which he examined the economic/welfare ancillary benefits, Barker (1993) modeled the reduced traffic accidents associated with the proposed EU carbon/energy tax. Not surprisingly, he found that even a small tax increase would lead to a significant reduction in fatal and non fatal traffic accidents. In the area of industrial safety one can certainly imagine that the broadscale economic effects associated with

energy price changes could lead to output changes which, in turn, altered overall accident rates (e.g., substitution computer software for steel production), although the net effects on accidents are not clear. The Barker study is the only one we are aware of that has explicitly quantified the link between carbon mitigation policies and safety.

2.2.5 *Other*

Depending how broadly one defines ancillary benefits, it is conceivable that other categories of ancillary benefits are also relevant. There is a well-known literature indicating that the move to performance-based regulation and away from technology-specific approaches can enhance innovation. To the extent that performance-based GHG mitigation policies substitute for technology-specific regulation, overall innovation may be encouraged. There is also a small but growing literature specifically focused on induced technological change, i.e., how much additional economy-wide innovation, if any, would be stimulated by GHG mitigation policies. Unfortunately, there is no consensus of views in this evolving field. (For differing approaches see Grubb et al, 1995; Goulder and Schneider, 1999; and Goulder and Mathai, 1998) If one believed that GHG mitigation policies truly accelerated the overall rate of technological change then one might want to include ‘GDP growth’ as an explicit ancillary benefit.

2.3 *Avoided costs*

The most common way to think about categories of ancillary benefits associated with GHG mitigation policies is in terms of the direct effects on health, ecology, safety or other endpoints. However, depending on the types of policy in place GHG mitigation policies can also affect the cost of achieving particular policy goals. Burtraw and Toman (1997), EPA (1999), and Burtraw *et al.* (1999) all estimate abatement cost savings for SO₂ reductions under the allowance trading program as an ancillary benefit of GHG reduction policies. The basic idea is quite simple: as long as the SO₂ cap is binding, policies to reduce GHG emissions from the power and industrial sectors will not lead to further reductions of SO₂ emissions. However, significant abatement cost savings may accrue to those purchasing or otherwise acquiring SO₂ permits freed up by the GHG policy’s induced SO₂ reductions. For example, the EPA study examined alternative levels of GHG mitigation to assess their impacts on other pollutants in the year 2010. The study found that under a business-as-usual scenario 82 GW of sulphur scrubbers would be installed. With the modeled GHG policies in place, fuel switching reduces the scrubbers required to 63 GW for an annual saving of almost \$500 million. Interestingly, there may be a tendency to generalize this result to policy contexts where the cap is softer than in the SO₂ trading program. Arguably, Lutter and Shogren (1999) have assumed that the proposed ambient fine particle standard, particularly as it applies to the Los Angeles basin, is tantamount to a hard cap against which one can credit cost savings arising from GHG mitigation policies. For a variety of reasons discussed in a later section, we believe the attribution of large cost offsets in this instance is not appropriate.

2.4 *Adaptation*

Although the literature has focused on the ancillary benefits associated with mitigation policies, there may be significant ancillary benefits associated with adaptation policies as well. For example, actions to adapt to the effects of climate change, ranging from individual decisions to turn on air conditioners in the summer, to more aggressive (communal) actions to build sea walls or corridors for wildlife to

migrate, could have implications for air pollution (probably adverse) or ecological health (potentially positive).

A recent presentation by Scheraga (1999) highlights the potential for ancillary benefits from adaptive responses that could be taken to address climate change. Egypt, for example, has a number of populous and low lying areas vulnerable to sea level rise and thus threatened by salt water intrusion. Water resources in the Nile River Basin would be threatened with resulting risks to several important sectors. Agriculture, which would be affected directly by temperature changes, would also be indirectly affected by changes in the availability of water from the Nile. Heat stress would directly threaten human health. Various adaptation options exist to reduce these vulnerabilities. Improving irrigation efficiency, for example, would yield benefits to agriculture and, potentially, to human health. Scheraga points out, however, that such a policy would also reduce the demand for Nile River water, thus yielding benefits (or cost offsets) for the supply of drinking water, for hydropower requirements, etc. To our knowledge the ancillary benefits of adaptation policies have not been empirically examined, although this may be a fruitful area of research. [See also Strzepek, *et al.* (1995)].

2.5 *Air pollution and health*

The type of ancillary benefits most intensively studied in previous research involve the health effects associated with reductions in criteria (conventional) pollutants. A number of authors have recently reviewed the literature on this issue (Ekins 1996; Burtraw and Toman 1997; Burtraw *et al.* 1999; Pearce 2000; RIVM 2000). In this section we consider the same literature, by updating (slightly) previous reviews, and by including the handful of ancillary benefit studies conducted in developing countries. Table 1 enumerates the recent studies, along with a listing of the key methodological issues associated with each of them.

The most robust finding in this literature is that there are, indeed, significant ancillary benefits arising from the reductions in conventional pollutants associated with GHG mitigation policies, although the results vary considerably according to the countries and sectors studied, the nature of the policies examined, and other factors. This basic finding about the existence of potentially significant ancillary benefits holds up across every study we are aware of, which includes analyses conducted in the US, Europe, and a limited number of developing countries and economies in transition. In many of the studies the results are driven by reductions in NO_x and CO. Depending on the country, smaller and generally less important contributions come from reductions in VOCs and/or Pb. Direct particle emissions (TSP or PM₁₀) factor into a number of studies. However, secondarily formed compounds, e.g., sulfates and nitric acid, are not treated in a consistent manner in the literature. Thus, a potentially major source of elevated particulate concentrations – with potentially large health effects – is excluded from most of the studies.

Another finding from the literature is that the estimated ancillary benefits are considerably higher in Europe and in the limited literature on developing countries than in the US. Certainly the findings for developing countries are not surprising, given the higher baseline emissions levels for most conventional pollutants, the lack of in-place or planned standards, and the more aggregate level of modeling typically used in developing country studies.

The explanation for the differences between US and European studies, however, is a bit more complicated. Ekins (1996) reviews the (heretofore largely unpublished) European literature and indicates a best estimate of \$273 (1996 dollars) of ancillary benefits per ton of carbon reduced. The studies underlying this estimate include the initial fixed-coefficient papers plus a more recent series of analyses based on macro models [Barker *et al.* (1993), Alfsen *et al.* (1995)]. The economic valuation

underlying these calculations are drawn from an early literature with values that are higher than those currently used in the US. (For current values used by the US Environmental Protection Agency, see EPA (1997)). Unfortunately, the valuation literature reviewed for the ExternE Project – Europe’s comprehensive fuel-cycle model of environmental impacts of new (1995) vintage power plants - was not incorporated into the Elkins review. Use of the ExternE values, which are more in line with the lower US numbers, would have reduced the European ancillary benefit estimates considerably. Apart from these valuation issues, and differences in baseline assumptions (discussed below), the discrepancies between the US and the European results are probably attributable, as Burtraw *et al.* (1999) note to several other factors: a) the more aggregate level of modeling in the European studies, b) greater population density in Europe and c) the fact that a greater proportion of the US emissions are deposited offshore rather than on-shore as in Europe.

A corollary finding from this literature is that the estimates of ancillary benefits have declined over time, at least as regards studies within a single country or area. With the exception of the Lutter/Shogren study (discussed below) this is most evident in the US estimates, where some of the early studies derived estimates as high as \$80/ton of carbon abated (not shown in Table 1). More recent estimates are in the range of \$3-6 per ton of carbon abated, based on policy simulations involving modest GHG reduction policies (e.g., \$10/ton carbon tax). A similar story holds for the European studies although, as noted, the estimates are generally higher and the secular decline is not as dramatic.

An equally important finding from the literature is that the differences in the valuation of the ancillary benefits – which vary by an order of magnitude – stem not only from the different policies and sectors studied, but from the great divergence of methods and models used in the analyses. The earlier studies typically employed a fixed coefficient modeling approach for estimating ancillary benefits (e.g., Pearce 1993). They attempted to calculate an average relationship between the reduction in carbon emissions and the reduction in conventional pollutants. While this served as a useful exercise in bringing to light the basic concept of ancillary benefits, it is now widely recognized that ancillary emissions reductions have no necessarily absolute or proportional relationship to carbon reductions. In fact, they can vary in complex ways depending on the nature of the GHG policies themselves, spatial location, and a host of other factors. For example, GHG-reduction policies that raise gasoline prices by a small amount may reduce driving somewhat and may result in ancillary emissions reductions roughly proportional to GHG reductions. However, larger changes in gasoline prices may result in changes in the fuel and vehicle mix that result in disproportionately larger reductions in ancillary emissions.

The early fixed-coefficient approach has now been supplanted by simulation studies which examine the effect of particular GHG reduction policies on nonGHG emissions in the context of a specific model. The clear advantage of the simulation approach is that it endeavors to capture more of the underlying complexity of the relationship between GHG policies and ancillary benefits. For example, in their work on electric utility models, Burtraw *et al.* (1999) find that the incremental value of ancillary benefits from NO_x reductions per ton of carbon reduced declines with more aggressive carbon policies, although that calculation does not include the additional SO₂ reductions that may also accrue once SO₂ emissions fall below the legally mandated cap.

As Burtraw *et al.* (1999) note, the US simulation models are generally of two varieties, reflecting differences in approaches to estimating emission changes. In the first category are those studies which have linked economy-wide CGE models with estimates of emission rates in various industries to relate increases in the price of energy (generally via carbon taxes) to changes in investment and output and, in turn, to changes in CO₂ emissions, and in criteria air pollutants. The second category consists of studies, which use disaggregated models of the electric utility industry to look at changes in

investment, utility operations, and conventional pollutant emissions associated with institutional and pricing reforms in the utility industry. In addition to the introduction of carbon taxes, examples of the policy changes studied in the disaggregated models include Green Lights, Motor Challenge and other voluntary programs embodied in the 1993 Clinton Administration Climate Change, and reform of electricity transmission pricing.

A fifth and critically important observation from this literature concerns the importance of the geographic location of the emission reductions. In the early 1990's major analytic efforts – carried out on both sides of the Atlantic – focused on the comprehensive effects of electricity fuel cycles (Lee *et al.* 1995; EC, 1995; Rowe *et al.*, 1995). One of the major conclusions of these efforts is that the environmental impacts and, more specifically, the monetized value of those impacts, depend critically on the geographic location of the emission changes. For example, Lee *et al.* (1995) estimate that the monetized value of the health impacts of a new coal-fired power plant are an order of magnitude higher for a plant located in Tennessee than in the less-densely populated state of New Mexico. Similar findings arise from all three of the cited fuel cycle studies. Other factors, including the potential for a nonlinear relationship between emissions and pollutant concentrations, or between concentrations and health effects, further enhance the importance of the complex, location-specific models.

Unfortunately, the aggregate CGE models cannot generate outcomes at a spatially-relevant level. The international CGE models typically divide the world into large regions (e.g., North America is typically considered to be one region). National models of the US treat the entire nation as a single area, although details are often available at the industry level. Thus, by their very design, the large CGE models are unable to capture the important locational differences that effect the valuation of emission reductions.

In contrast, the disaggregated models have the capacity to generate geographic-specific results. For example, the Holmes *et al.* (1995) study developed emission estimates on a geographic basis, according to the North American Reliability Council (NERC) Regions. The study also estimated emissions changes according to season and time-of-day, both of which would be important for any analysis of changes in ozone concentrations. Using the Holmes *et al.* emission estimates, Burtraw and Toman (1997) conducted a geographic analysis of atmospheric transport of pollution and the corresponding population exposure via the PREMIERE model. They estimated the benefits of the calculated NO_x reductions at \$3.22 per ton of carbon reduced, roughly the same result obtained with the HAIKU model. (Burtraw *et al.* 1999).

Table 1. Recent ancillary benefits studies*

Study	Spatial Area	Sector	Policy Assumption	Average Ancillary Benefits \$tC (1996 dollars)	Pollution Cost Savings Included	Comment
Lutter and Shogren, 1999	LA county	All	1990 Clean Air Act	\$300.	Yes	Integration of models and external calculation
Burtraw, <i>et al.</i> 1999	US	Electric	1990 Clean Air Act plus 1999 SIP Call	\$3. (for \$10 carbon tax)	Yes	Focus on NO _x and SO ₂ . Visibility and ozone benefits not considered
Cifuentes <i>et al.</i> 1999	Chile	All	Current policies explicitly considered (including 1997 Plan)	\$20-70	No	Six air pollutant categories. Detailed energy categories. Results sensitive to benefits transfer.
Dessus and O'Conner, 1999	Chile	All	Current policies explicitly considered, especially for PM ₁₀ and Pb	\$150-300 (1992 \$ and exchange rates)	No	Seven air pollutant categories, including Pb. Results sensitive to benefits transfer methods.
Aunan <i>et al.</i> 1998	Hungary	All	1990-1992 policies assumed in place, including Pb in gasoline reductions.	NA	No	Bottom-up approach. Limited economic modeling. Multiple pollutants, endpoints and types of ancillary endpoints considered. Extensive benefits transfer.
Working Group on Public Health and Fossil Fuel Combustion, 1997	Global	All	OECD nations use 1990 Clean Air Act Standards; non OECD nations use same standards for mobile sources by 2020 and 1970 standards for stationary sources by 2020	Results not monetized	No	PM10 is sentinel pollutant; highly stylized analysis to develop global impacts
Ekins, 1996	Various	All	Alternative cases assume compliance with first SO ₂ and NO _x protocols	\$273	Yes	Synthesis of several other studies
Holmes, <i>et al.</i> / PREMIERE 1995	US	Electric	1990 Clean Air Act	\$3.22**	No	Motor Challenge Program; includes secondary nitrates, excludes ozone effects

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Alfsen, <i>et al.</i> , 1995	Norway, EU	Electric	Alternative cases assume compliance with SO ₂ and NO _x protocols	24-452, 21+ ***	Yes, but not fully calculated	Human health, accidents, congestion, acidification of forests and fresh water lakes considered
EXMOD 1995, as derived in Burtraw and Toman (1997)	New York State	Electric	1990 Clean Air Act	\$23.79**	No	Reduced use of single coal plant in N.Y.; only PM, NO and SO (assuming emission cap in place); includes secondary particulates and ozone effects
Boyd <i>et al.</i> 1995	US	All	Economy-wide carbon tax	\$39.79	No	Human health and visibility effects calculated from reduced emissions of all criteria pollutants
Barker, 1993	UK, US, Norway	All	Various cases with alternative assumptions about meeting targets	125-282; 332, 254-386***	No	Human health, traffic accidents, congestion considered
Goulder/Scheraga and Leary, 1993	US	All	Economy-wide carbon tax with stabilization at 1990 levels in 2000	\$33.36**	No	All criteria pollutants, no secondary particulates or ozone
Dowlatabadi <i>et al.</i> /PREMIERE 1993	US	Electric	Pre 1990 Clean Air Act	\$2.95**	No	Seasonal Gas Burn; includes secondary nitrates, excludes ozone effects

* Previous studies based on fixed emissions ratios are generally excluded from this Table.

** Calculated by Burtraw *et al.* (1999).

*** As reported in RIVM (2000).

3. Baseline issues for assessing ancillary benefits

We have identified five issues where baselines could be significant in assessing ancillary benefits. These issues, which are distinct from those that are generally considered in the baselines of large-scale economic models, include: policies/regulations as they specifically affect the different types of ancillary benefits, technology development and diffusion, demography other than the aggregate population, economic activity other than aggregate measures of performance, and natural baselines, including the assimilative capacity of natural systems. Other categories may also be relevant.

3.1 *Types of baselines*

3.1.1 *Policy*

Current and assumed future laws, policies, and regulations (and degree of compliance) are critical factors for assessing the relevant ancillary benefits baseline. Although environmental policy is an important element of the baseline it is not the only relevant area of concern. In fact, policies that indirectly affect baseline emissions of ancillary benefits may be as important to consider as those directly governing emissions. Depending on the issue, one can imagine that health policy (e.g., policies aimed at universal or improved quality of health care), transportation policy (e.g., CAFÉ standards), agricultural policy (e.g., nonpoint source standards which might affect water runoff and thus baseline water quality), energy (e.g., voluntary program designed to encourage the dissemination of high efficiency motors in industry such as DOE's Motor Challenge), economic regulation (e.g., deregulation of the electricity generation), and tax policy (e.g., proposed EU carbon/energy tax or US BTU tax) could all have significant impacts on the nature and magnitude of ancillary benefits.

To date most of the studies explicitly addressing policy baselines have focused on air pollution issues. However, a few studies have been conducted in other areas as well, including energy policy [e.g., Holmes, *et al.* 1995; US DOE and US EPA, cited in Dower and Morgenstern (1997)], and transportation (Barker 1993). A number of these policy areas are inter-related. For instance, to get a good fix on the air pollution benefits of GHG policies in the U.S. one needs to make assumptions about a broad array of issues affecting the pace and consequences of electricity restructuring—capturing effects on fuel mix, activity levels, abatement technologies, and the spatial distribution of these effects. If one categorizes electricity restructuring as a GHG reduction policy, then any emissions reductions (or increases) from restructuring would count as ancillary benefits (costs). At a minimum, such policy assumptions need to be explicit.

3.3.2 *Technology*

Assumptions about the economy-wide rates of technology/efficiency improvements are usually transparent in the macro-level analyses of the costs of GHG reductions, e.g., the AEEI (autonomous energy efficiency increases). However, these assumptions may not be sufficiently detailed to credibly estimate future baselines for ancillary emissions. Often, the effect of the 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 a car ages are all critical components for estimating baseline ancillary emissions, but are not generally stated or even addressed in ancillary benefit calculations. Care also must be taken to be sure that the ancillary emissions are consistent with assumptions about the future mix of gasoline, diesel, and vehicles using other types of fuels. Also, there is evidence that emissions are lower in vehicles with higher gas mileage (Harrington, 1997).

3.3.3 *Demographic*

While the 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 benefits. For example, continued improvements in the health status of the population will effect the estimation of ancillary benefits in a number of ways. Healthier people are less susceptible to many environmental conditions, including some types of air and water pollution. The willingness to pay (WTP) for health improvements may also vary with the health status of the population, although a recent literature review suggests that such differences only become significant above risk levels of 50 per cent (UK Department of Health 1999). At the same time, increasing urbanization tends to expand the size of the population exposed to high pollution levels while the growing elderly population tends to increase susceptibility to air pollution damages.

Although these elements are sometimes considered in economic benefit studies, to our knowledge none of them has been explicitly incorporated into the ancillary benefits literature. The sole exception is Burtraw *et al.* (1999) which included population projections according to geography, age and income in their analysis.

3.3.4 *Economic*

Assumptions about baseline levels and growth rates of aggregate economic activity (GDP) are essential to understanding the direct benefits and costs of GHG mitigation policies. However they may not be sufficient to understanding the ancillary benefits. Disaggregation at the industry level – already present in a number of the large scale models – is clearly critical to understand shifts from pollution-intensive industries to the service sector. In addition, to get a full understanding of the ancillary benefits it is also important to understand the size of the population exposed to conventional pollution. This, in turn, requires information on the spatial location of the emissions vis-à-vis the population. As noted earlier, the level of geographic detail varies considerably among the ancillary benefit studies. Certainly none of the large-scale CGE models are capable of addressing geographic issues.

3.3.5 *Natural Activities*

Our final baseline category concerns the natural baseline, particularly the assimilative capacity of the natural system. Consider the case of the Adirondack watersheds, which are particularly sensitive to potential acidification from atmospheric deposition of sulfur and nitrogen, in part because of the cool temperatures, shallow soils with low base saturation, short growing seasons, and the long history of elevated sulfur and nitrogen deposition. Because of the scientific uncertainty in the estimated time to nitrogen saturation, the range for the future baseline of chronically acidic lakes is enormous. One recent study found that if saturation was assumed at 50 years then the percentage of lakes that are chronically acidic – 19 per cent now – could more than double by 2040. Alternatively, if it is assumed that saturation is never reached, the percentage of chronically acidic lakes could fall to 11 per cent or less by 2040.¹

Clearly, such wide swings in assumptions could have major implications for ancillary benefit estimates. Interestingly, recent studies in China find that nitrogen deposition into surface water transforms natural toxins into potent carcinogens. Although limited quantitative work has been done on this issue, it suggests the possibility of other types of health and ecological benefits associated with reduced nitrogen deposition (Wu *et al.*, 1998). Overall, it is clear that both basic and applied research are needed in this area.

4. **Treatment of baseline issues in the ancillary benefit literature**

In general, the early ancillary benefits papers explored the broad conceptual issues and developed preliminary estimates with only limited specificity about the baseline. Several recent papers have explored the baseline issue in greater detail, although the applications have generally been limited to environmental health.

In considering how the baselines affect the estimates of ancillary benefits, it is important to consider several aspects of the studies. Perusal of Table 1 indicates that the geographic scope of the studies ranges from county-specific (Los Angeles) to global, although the preponderance of the papers focus on the US. As noted, a number of the studies use disaggregated sector-specific models of the electric utility sector which include significant geographic detail as opposed to the more aggregate models of the entire economy.

The studies reported in table 1 focus almost exclusively on health issues. Inasmuch as health benefits generally represent a large portion of the known benefits of pollution reduction (70-90 per cent), this is certainly a good place to start, although it is not necessarily the only important ancillary benefit. Second, environmental policy baselines are the principal if not the only type of baselines explicitly considered in this literature. None of the studies explicitly considered ancillary benefit baseline issues for nonenvironmental policies (e.g., energy, transportation, etc) or for nonpolicy areas (e.g., technology, demographic, economic or natural activities), although some of these issues are mentioned. Thus, this literature should be seen as representing an important category of ancillary benefits but not the only one.

¹ The information in this paragraph on the Adirondack watershed is drawn from a background paper by Cook, *et al.* (1999).

In the US several of the recent studies explicitly considered at least one and, in some cases, multiple aspects of the 1990 Clean Air Act. The SO₂ program is the most commonly modeled of recent policies, although it is not consistently handled in the literature. Some of the early studies examine the possibility of further SO₂ reductions associated with modest GHG mitigation policies. The more recent papers recognize the fixed nature of the cap although, as noted, only a few of the papers attempt to calculate avoided costs. Only one paper goes beyond the 1990 Clean Air Act to consider recent efforts to control interstate transport of NO_x. This is an important addition to the literature because NO_x is a key source of secondarily formed fine particles which, in turn, have been linked via epidemiology studies to elevated mortality rates. In Europe the Second Sulfur Protocol was not been explicitly modeled in any of the papers reviewed by Ekins (1996), although the First Sulfur Protocol was considered in several studies. One of the Chilean papers considered full implementation of the Decontamination for the Metropolitan Region (Santiago). In the single global study specific assumptions were made about the technologies in place in different regions at future dates.

Not surprisingly, small differences in the policy baselines can yield large differences in the value of ancillary benefits. Although there are few examples of sensitivity analyses designed to test the importance of baselines, some evidence is available on this point. Thus, when full account is taken of the Second Sulfur Protocol, Burtraw *et al.* (1999) estimate that the mean value of the ancillary benefits calculated by Ekins (1996) for European nations declines by about one-third.

In the SO₂ program a facility that reduces its emissions below its own regulatory limit displaces the need for abatement at another facility (or at its own facility in the future). The CGE models do not consider this issue at all. Only the sector-specific models are capable of addressing this issue adequately. The benefits of avoided investments in SO₂ abatement are generally additive with respect to other categories of benefits. Burtraw *et al.* (1999) found that for moderate carbon policies that leave the SO₂ cap unaffected, SO₂ abatement cost savings of about \$3 per ton carbon reduced should be added to the \$3 per ton ancillary benefits identified with the modeled NO_x reductions. In this instance consideration of the avoided abatement costs effectively doubles the estimates of the ancillary benefits for the case of moderate carbon policies.

Other than the previously cited EPA study, the only other analysis to explicitly consider these avoided costs of regulation is by Lutter and Shogren (1999). In a widely-circulated memo, Lutter and Shogren consider the avoided cost of abatement in the context of a “capped” program very different from the SO₂ cap, namely the criteria air pollutant program. Unlike most of the other studies listed in Table 2, they present a fairly simple analytical formulation of how changes in carbon emissions affect the emissions of conventional pollutants. Their empirical work focuses on cost savings in attaining the newly proposed ambient particle standard PM_{2.5} (particulate matter of less than 2.5 microns in diameter) in Los Angeles. They focus on Los Angeles as the marginal area since, as they note, “[it] is likely to be the ‘last’ area to come into compliance with EPA standards.”

Overall, Lutter and Shogren estimate avoided costs of about \$300 per ton, although there are a number of reasons to question their findings. First, the PM_{2.5} standard is not actually in effect since it has been blocked by the D.C. Circuit Court of Appeals. However, even if the PM_{2.5} standard as originally promulgated were to become effective, full compliance would not be assured.

For the PM_{2.5} and other costly standards, care must be taken to consider the degree of likely compliance when developing baselines. The international literature is replete with anecdotes about countries with strong laws on the books but weak enforcement. Certainly one would not want the baseline assumptions for some countries to be taken from too literal a reading of environmental laws in those countries. Yet, even where there is a strong history of enforcement some of the same problems can exist. While the US acid rain program is an example of a program with a very strong performance record, the story for other programs is less sanguine. For example, more than half the US population lives in areas that are currently in violation of the ambient ozone standard. Full compliance is not anticipated for decades, at best. Thus, it would be imprudent to assume full compliance with the ambient ozone program when estimating either ancillary benefits or avoided costs. Thus, even apart from the precarious legal nature of the PM_{2.5} standard, we think it is imprudent to assume, as Lutter and Shogren do, that it would be fully implemented in Los Angeles or in other high cost areas over the next several decades.

A further area of concern about the Lutter and Shogren calculations concerns the likely carbon reductions to occur in Southern California as a result of at least modest GHG mitigation policies. Models of the US economy estimate that under an economically efficient control regime about two-thirds of reductions are likely to come from the electricity utility sector. Yet, at present there is no coal based generating capacity in Southern California.² Thus it is unlikely that GHG mitigation policies would generate the PM_{2.5} reductions in the Los Angeles area that would be consistent with the ancillary benefit estimate of \$300 per ton of carbon even if the standards were in place and enforced in Southern California.

Our conclusion on this point is the simple one that all standards, even all capped standards, are not alike in terms of their effect on ancillary benefits. Our suggestion is that analysts should consider the degree of likely compliance with individual standards, especially costly ones, when developing baselines for either ancillary benefits or avoided costs.

A final concern about baseline issues arises when a GHG mitigation policy is associated with certain negative ancillary benefits. In the developing country context the most relevant example concerns a GHG mitigation policy that has the (unintended) effect of slowing the pace of rural electrification, e.g., by raising the relative price of electricity vis-à-vis other (unregulated) energy sources. A well specified baseline would presumably capture the expected growth in rural electricity use and the corresponding substitution away from dirty and inefficiently combusted fuels, e.g., coal or biomass. Simulation of a model with such a baseline would properly capture the negative ancillary benefits associated with the GHG mitigation policy (e.g., higher morbidity and mortality associated with the increased indoor and the outdoor exposure to fine particles and other pollutants). Interesting work in this area has recently been carried out by Wang and Smith (1999).

² I am indebted to Dallas Burtraw for pointing this out to me.

5. A scorecard for estimating ancillary benefits

5.1 Recommendations

Recognizing the complex issues and multiple objectives involved in establishing a credible and comprehensive baseline, it is tempting to create a type of scorecard to heighten awareness to the critical problem areas. Such a scorecard could involve tabular or other visual presentation for developing both quantitative and qualitative information on key baseline issues. In this section we begin that task by distilling the key problem areas identified in the previous sections and developing a series of recommendations to guide the preparation of ancillary benefit estimates.

As a starting point, we refer to Table 2, which arrays the multiple ancillary benefit areas discussed in Section 2 along the horizontal axis and the various baseline issues presented in Section 3 along the vertical axis. The Xs refer to areas where previous studies have been identified. The obvious temptation to call for more information or analysis must be considered in a value of information framework. In the end, of course, there is no substitute for judgement on the part of the analyst concerning the relative importance of the issues identified below.

Recommendation #1: Consider as many types of ancillary benefits as practicable

This is probably the most basic issue of all. Referring to Table 2, we have identified four potentially important categories of ancillary benefits: health, environmental, economic/welfare, and safety. In addition, other categories may be relevant. To date most of the 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.

Recommendation #2: Consider as broad as possible a set of baseline issues as practicable

We have identified five areas of potential concern for the development of baselines: policy/regulatory, technology, demography, and economic and natural activities. Others may be relevant as well. Each of the baseline issues, in turn, has sub-elements that may be important. When considered in light of the multiple categories of ancillary benefits, there could be as many as one hundred (or more) baseline issues of concern. Of course, not every issue applies to every GHG mitigation policy, and many of the potential issues in Table 2 have not been seriously examined in the literature to assess their quantitative importance. Nonetheless, it might be appropriate for researchers to at least consider a list of this sort. Clearly they would choose to reject many of the categories as either unknown, unknowable or irrelevant. But the very act of considering such a list might spur new research ideas.

Table 2. Ancillary benefit/baseline issues not generally included in GHG models
Categories of Ancillary Benefits

(1) Baseline Issues	(2) Health	(3) Ecological	(4) Economic/ Welfare	(5) Safety related	(6) Other*
Policy/Regulatory					
Environmental					
Air	X	X	X	X	
Water					
Waste					
Other					
Health					
Transportation	X			X	
Agriculture					
Energy					
Economic Regulation	X				
Tax					
Other					
Technology					
Innovation					
Diffusion					
Demography					
Population Health Status					
Spatial Distribution					
Age Distribution					
Economic Activity					
Subsectoral Composition					
Spatial Distribution					
Natural Activity					
Other					

* Categories suggested in the literature include employment, technological change (which could lead to an increased GDP growth rate), community severance (e.g., loss of neighborhood due to heavy traffic flows), and others.

Recommendations #1 and #2 apply to all ancillary benefit studies of GHG mitigation policies. They represent a call for care and completeness when thinking through potential ancillary benefit issues. Naturally, these recommendations must be tempered by the costs and the benefits of developing estimates according to multiple ancillary benefit/baseline categories. In the one ancillary benefit area which is most developed in the literature - namely health - a more specialized set of issues apply.

Recommendation #3: When focusing on air pollution issues consider the full set of relevant pollutants and source categories

Often only a subset of the relevant pollutants are considered in ancillary pollutant studies. The early ancillary benefit studies tended to focus on a limited number of pollutants. It is now widely recognized that multiple pollutants may yield significant ancillary benefits. The more recent US and European studies have focused on NO_x, SO₂, and PM₁₀. 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 benefits associated with reduced lead exposure in a country like Chile where lead continues to be widely used as an octane booster in gasoline.

Recommendation #4: When new or anticipated standards are considered in the baseline, consider the precise form of the standards

When an emission standard takes the form of a hard cap, as the case of SO₂ emissions covered under the Clean Air Act, it is particularly important that the models accurately reflect the precise form of the standard. As several US studies have shown, because of the nature of the cap, moderate carbon policies do not generally induce further SO₂ reductions. In those cases, however, it is important to calculate the avoided costs associated with the GHG mitigation policy. Of course, with more aggressive GHG mitigation policies it may become economic to reduce SO₂ emissions below the cap, although the precise level where the cap is breached has not been fully explored in the literature.

Recommendation #5: Be sure to consider the anticipated degree of compliance with new (or existing) standards

It is not generally appropriate to assume that all emitters will be in full compliance with new or existing standards. Although this is not always a distinction of importance, an inappropriate assumption about compliance can introduce significant bias into the estimation of ancillary benefits. In the U.S., for example, with particulate and ozone standards now under revision, and with new emphasis on reducing NO_x, it is particularly important to include new and anticipated standards in developing baselines. Failure to include such standards will tend to overstate environmental savings. It may also overstate the costs of the CO₂ reductions by overstating the opportunity costs of potential substitution away from old technologies. Which one of these factors is greater depends on the relative costs, elasticities, etc. In one case reviewed here, the authors assumed that all polluted areas in the US would be in compliance with the proposed PM_{2.5} ambient air standard in little more than a decade. Given the history of compliance with other costly ambient standards in the US, we do not believe this is a realistic assumption for purposes of calculating ancillary benefits.

Recommendation #6: Consider the location of the expected reduction in pollution in developing estimates of ancillary benefits

As the social costing literature has vividly demonstrated, 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. Meteorology and other factors affecting the transformation from emissions to pollutant concentrations can also be critical. It is thus vitally important to consider the location of contemplated emission reductions when making estimates of ancillary benefits.

Recommendation #7: Use disaggregated, geographic-relevant models whenever possible in order to capture the complex effects underlying ancillary benefit estimates

Because of the underlying complexities of industry and geographic-specific factors, disaggregated models represent a superior approach for developing accurate estimates of ancillary benefits. Aggregate models, which have many advantages for the study of GHG mitigation policies, are not well suited to capture the important nonlinearities involved in estimating ancillary benefits.

Recommendation #8: Beware of the tendency to overstate baseline emissions

There may be a (natural) tendency to overstate baseline emissions of conventional pollutants. While it is difficult to demonstrate the accuracy of emission baselines in ancillary benefit studies, two observations can be made. First, as shown in table 1, if one omits the Lutter and Shogren (1999) analysis, there is a clear tendency for the estimated ancillary benefits to decline over time, at least in the US literature. Inspection of these studies suggests that one of the principal reasons for the downtrend in estimates is the secular refinement in the baseline estimates. It is probably fair to say that from today's vantage point the early estimates of ancillary benefits implicitly overstated the growth in future emissions. The more recent estimates have reduced the estimates of baseline growth and, correspondingly, reduced the estimates of ancillary benefits.

A second piece of evidence on this point comes from a recent review of the accuracy of cost estimates used in environmental and occupational regulation, including a breakout showing the accuracy of the baselines. Harrington *et al.* (2000) assembled a dataset consisting of 28 environmental and occupational regulations or policies for which detailed *ex ante* as well as *ex post* cost estimates had been prepared. About half of the regulations were issued by the US EPA with the remainder issued by the US Occupational Safety and Health Administration (OSHA), the state of California, Canada, Norway and Singapore. Most of the cost analyses applied to relatively large rules and reflected considerable effort on the part of the regulatory agencies to prepare the estimates.

The results suggest a tendency – albeit not an iron clad rule - for the costs of regulations to be overestimated. One of the reasons for this overestimation is that the quantity of emissions reductions associated with the regulations tends to be overestimated as well. Inaccurate prediction of emissions reductions can occur through mis-estimation of the baseline emissions that would exist without the regulation or through compliance problems. Cited examples of baseline errors in the Harrington *et al.* study include the US SO₂ program. In that case the analyses did not foresee an estimated two million tons of reductions that occurred as a result of railroad deregulation and other factors unrelated to the EPA regulations (Carlson, *et al.*, 2000). The authors note that “...curiously, our data-set contains no baseline underestimates.” In fact, they suggest, “...agencies may have a strategic interest in enhancing the potential seriousness of the problems they are regulating.”

Research in this field is limited and the cited study – which contains the largest sample of any published study – should be seen as preliminary. Nonetheless, the lesson is clear: beware of overestimating baseline emissions.

Recommendation #9: Consider as many uncertainties as practicable when developing ancillary benefit estimates

This is an obvious but critically important recommendation. With or without credible information on the issues described above it is essential that explicit uncertainty analyses be conducted. Even the simple use of sensitivity analysis can be helpful in highlighting the key uncertainties.

5.2 *Integration between economic modelers and ancillary benefits experts*

There has generally been a lack of interface between large scale economic modelers and ancillary benefits experts. More than any other single event, the third assessment report (TAR) of the IPCC has served to raise awareness in the modeling community about the importance of these issues. Nonetheless, the current state of intellectual exchange between the large scale economic modelers and the ancillary benefits experts is quite limited.

Recently, the IPCC Special Report on Emission Scenarios (SRES) (IPCC, 1998) has been the subject of extensive discussion and review concerning the characterization of future GHG emissions. Little attention has been focused on the emission scenarios for nonGHGs or on the relevance of these scenarios for the calculation of ancillary benefits. Overall, there are a number of helpful elements in these scenarios, although many questions arise concerning their usefulness to the modeling activities currently underway in the IPCC.

The helpful elements in the scenarios concern the number of nonGHGs considered and the spatial detail available for these scenarios. SRES developed emission scenarios for four nonGHGs: SO₂, NO_x, NMVOCs, and CO. Annual emission estimates are available for four global regions *and* for one degree by one degree grids within those regions, 1990-2100. These estimates, in turn, are derived from the group of models used by SRES: AIM (National Institute of Environmental Studies, Japan); ASF (ICF Kaiser, USA); IMAGE (RIVM, the Netherlands); MESSAGE (IIASA, Austria); MARIA (Science University of Tokyo, Japan); and MINICAM (PNNL, USA). Not surprisingly, SO₂ has been the most carefully modeled, although all four gases have been studied in some detail. Limited information has been published on the construction of these scenarios but, at least in the case of the SO₂ emissions, they are tied to an income-based parameterization – a so-called Kuznets curve (Smith *et al.*, 1999). Under these scenarios emissions follow a ‘U’ shaped pattern wherein emissions first increase with increasing use of fossil fuels (mostly coal) and then decrease as controls are implemented. In the IPCC parameterization controls are adopted somewhat more rapidly than would be predicted on the basis of the historical growth in GDP per capita in the US and other developed countries. The one degree by one degree grids are based on an apportionment of emissions within the four regions modeled.

Unfortunately, at least on the basis of the published information, there is a lack of transparency about a number of key elements of these scenarios. While a Kuznets curve approach is appropriate for modeling long term trends (e.g., one hundred years), it is not particularly use for understanding the specific policies captured in the baseline. For the purposes of estimating ancillary benefits, it would be helpful to develop more detailed baselines for the nonGHGs for a shorter period of time (e.g., twenty years).

Finally, there is the critical question of how to integrate the information on nonGHG emissions into an economic analysis of ancillary benefits of GHG mitigation policies. The clear advantage of the large-scale economic models used by the IPCC is their ability to incorporate general equilibrium effects not available in the simpler models. However, given the level of aggregation of these models, it is not currently possible to develop ancillary benefit estimates which incorporate the industry and spatial detail needed to assure accuracy of these estimates. One recent CGE modeling effort in Sweden considered ancillary benefits, although it only developed estimates of emissions of nonGHGs as opposed to actual benefits (Nilsson and Huhtala, 2000). Yet it is the calculation of benefits that involves the more complex analytical and data issues

The SRES scenarios represent a positive step forward in their handling of nonGHGs. However, there is along way to go before even that level of disaggregation can be used to calculate ancillary benefits in the large-scale economic models. For the purposes of policy analysis, it remains an open question as to how best to integrate the two modeling approaches, at least in the near term.

6. Conclusions

Several points emerge from this review of baseline issues relevant to the estimation of ancillary benefits.

Ancillary benefits of GHG mitigation policies could potentially offset a significant portion of the costs of those policies. Inadequate consideration of these benefits could lead to the selection of GHG mitigation policies of inappropriate stringency or design. However, developing sound estimates involves many complex issues.

Baselines are an important component of ancillary benefit estimates. Small changes in baseline assumptions can lead to large changes in estimates of ancillary benefits. Currently, baseline issues are not addressed in a consistent manner in ancillary benefits studies. Problems of double counting as well as undercounting can be found in the available literature.

1. Most of the focus in the literature has been on ancillary health benefits associated with the reduction of conventional pollutants. Other categories of benefits e.g., ecological, economic/welfare, and safety need to be considered. Even when monetary valuation of these benefit categories is not possible, effort should be made to treat the outcomes as explicitly as possible, including the provision of both qualitative and quantitative information.
2. Only one element of the five potentially important baseline issues, namely, government policies and regulations, has been systematically treated in the ancillary benefits literature. Even there, however, the focus has been on environmental policies. Other policy baseline issues (e.g., energy, transportation, health, etc) have been generally ignored, as have the nonpolicy baseline issues (e.g., technology, demography, natural). All these need to be considered in an explicit manner in order to develop more credible ancillary benefit estimates.
3. Principally because of the importance of the location of emission reductions and of exposed populations, highly disaggregated models are the preferred tools of analysis for estimating ancillary benefits. Large errors can be introduced into the calculation of ancillary benefits by failing to consider issues of spatial location of emissions vis-à-vis potentially exposed populations.

4. As the ancillary benefit literature has evolved over the past decade estimates of ancillary benefits have declined somewhat. This is due in large part to the consideration of better articulated baselines and the use of the more disaggregated models which are able to incorporate the better articulated baselines. For example, current policies in the US are targeting individual power plants for NO_x reductions according to their contribution to ambient pollutant concentrations and the cost of making reductions at those power plants. To accurately represent such policies in the baseline – and thus avoid double counting - requires a highly disaggregated model with considerable spatial detail.
5. There are large information and modeling gaps, particularly concerning the spatial location of ancillary emissions. These gaps are especially large in developing countries, where it is difficult to model secular changes in the baseline in a sufficiently fine-grained manner to link the results to current policy developments. The use of Kuznets curves for modeling such emission scenarios is a promising approach, although the connection to current and planned policy developments is often tenuous.
6. The need for highly disaggregated and spatially relevant models to adequately incorporate the relevant baselines may conflict with other goals for the analysis of GHG mitigation strategies. For example, large CGE models which are used for cost estimation operate at a completely different spatial scale than the more localized models relevant to estimating ancillary benefits. The CGE models do not and, realistically, cannot soon incorporate this type of detail necessary for making sophisticated estimates of ancillary benefits.
7. Given our current inability to integrate the spatially relevant models for estimating ancillary benefits and the large scale economic models, probably the most pragmatic approach is to continue to rely on (an expanded set of) case studies of ancillary benefits estimates. The alternative, i.e., using the aggregate economic models to directly estimate ancillary benefits, would be costly as measured in a large loss of accuracy in the ancillary benefit estimates.

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