IIASA Policy Brief

Uncertainty in Greenhouse Gas Inventories

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This briefing highlights some of the issues and challenges arising from uncertainty in estimates of greenhouse gas (GHG) emissions and removals, explores how this uncertainty can be dealt with through uncertainty analysis techniques and improvements to science, and points to the implications of uncertainty analysis for policymakers working to reduce human impacts on the global climate.

Summary

- Calculations of greenhouse gas emissions (GHG) contain uncertainty for a variety of reasons such as the availability of sufficient and appropriate data and the techniques to process them.
- Understanding the basic science of GHG gas sources and sinks requires an understanding of the uncertainty in their estimates.
- Schemes to reduce human-induced global climate impact rely on confidence that inventories of GHG emissions allow the accurate assessment of emissions and emission changes. To ensure such confidence it is vital that the uncertainty present in emissions estimates is transparent. Clearer communication of the forces underlying inventory uncertainty may be needed so that the implications are better understood.
- Uncertainty estimates are not necessarily intended to dispute the validity of national GHG inventories but they can help improve them.
- Uncertainty is higher for some aspects of a GHG inventory than for others. For example, past experience shows that, in general, methods used to estimate nitrous dioxide (N_2O) emissions are more uncertain than methane (CH_4) and much more uncertain than carbon dioxide (CO_2). If uncertainty analysis is to play a role in cross-sectoral or international comparison or in trading systems or compliance mechanisms, then approaches to uncertainty analysis need to be robust and standardized across sectors and gases, as well as among countries.
- Uncertainty analysis helps to understand uncertainties: better science helps to reduce them. Better science needs support, encouragement and greater investment. Full Carbon Accounting (FCA)—or full accounting of emissions and removals, including all GHGs—in national GHG inventories is important for advancing the science.
- FCA is a prerequisite for reducing uncertainties in our understanding of the global climate system. From a policy viewpoint, FCA could be encouraged by including it in reporting commitments, but it might be separated from negotiation of reduction targets.
- Future climate agreements will be made more robust, explicitly accounting for the uncertainties associated with emission estimates.

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Uncertainties play a role in determining whether or not a country's commitments to reduce greenhouse gas emissions are credibly met.

Introduction

The assessment of GHGs emitted to and removed from the atmosphere is high on both political and scientific agendas.

Under the United Nations Framework Convention on Climate Change (UNFCCC), Parties to the Convention have published annual or periodic national inventories of GHG emissions and removals since the early 1990s.

Policymakers use these inventories to develop strategies and policies for emission reductions and to track the progress of these policies. Where formal commitments exist, regulatory agencies and corporations rely on inventories to establish compliance records. Businesses, the public, and other interest groups use inventories to better understand the sources and trends in emissions.

However, GHG inventories contain uncertainty for a variety of reasons, for example, the availability of sufficient and appropriate data and the techniques to process them. This uncertainty has important scientific and policy implications.

Until recently, relatively little attention has been devoted to how uncertainty in emissions estimates should be dealt with and how it might be reduced. Now this situation is changing with 'uncertainty analysis' increasingly being recognized as an important tool for improving national, sectoral, and corporate inventories of GHG emissions and removals.

What is uncertainty analysis?

Uncertainty analyses help scientists express a lack of exact knowledge about the true value of a quantity. Uncertainty may be expressed numerically or descriptively (e.g. in the statement "the circumference of the earth at the equator is *about* 24,901 miles, or is 24,901 miles *±1 mile*"). Knowledge about the uncertainty of an estimate provides additional information useful for decision making. For instance, we can use uncertainty analysis to help us choose between two actions with similar but unpredictable outcomes, by expressing the likelihood that each action will lead to the desired outcome.

Uncertainty analysis improves the monitoring of GHG emissions

There is a clear rationale for conducting and improving uncertainty analysis.

- First, uncertainty analysis can facilitate the comparison of emissions and emission changes across companies, sectors, or countries where different data or approaches have been used.

- Second, uncertainty analysis helps to identify the most prudent opportunities for improving the methods for estimating greenhouse gas emissions and emission changes.

- Third, uncertainties play a role in determining whether or not commitments on greenhouse gases are credibly met. Hence, solid uncertainty assessments have the potential to contribute to the stability of emissions trading markets by reinforcing the value of credible reductions.

At present, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are encouraged, but not obliged, to include with their periodic submissions on in-country GHG emissions and removals, estimates of the uncertainty associated with these emissions and removals, consistent with the Intergovernmental Panel on Climate Change's (IPCC) *Good Practice Guidance*. In addition, inventory uncertainty is monitored, but not regulated, under the Kyoto Protocol.

Uncertainty analysis can help improve inventories and risk management by recognizing the importance of uncertainties and by identifying and quantifying them. Uncertainty analysis is already a useful and necessary tool, but has some scope for improvement. However, improving the way in which we analyze uncertainty will never be as beneficial as improving the science on greenhouse gas emissions and removals, as it is through better science that uncertainty *per se* can be reduced. Ultimately, it is advances in the science that will enable scientists to handle uncertainties better in the future.

Policies to improve uncertainty in GHG inventories

In discussions during the recent Second International Workshop on Uncertainty in Greenhouse Gas Inventories, participants considered some pressing issues regarding how uncertainty can be dealt with through uncertainty analysis techniques and improvements to science, and the implications for policymakers working to reduce human impacts on the global climate.
Key points include:

■ Uncertainty analysis helps to understand uncertainties: better science helps to reduce them. Better science needs support, encouragement, and greater investment. Full Carbon Accounting in national GHG inventories is important for advancing the science. It could be included in reporting but separated from targets for reducing emissions.

■ Uncertainty is inherently higher for some aspects of an inventory than for others. For example, the land-use, land-use change, and forestry (LULUCF) sector has higher uncertainties than other sectors; estimates of N_2O emissions tend to be more uncertain than of CH_4 and CO_2. It is important to recognize the existence of these higher relative uncertainties. This raises the possibility that some components of a GHG inventory could be treated differently than others in the design of future policy agreements.

■ Improving inventories requires one approach: improving emissions trading mechanisms another. Inventories will be improved by *increasing* their scope to include Full Carbon Accounting. In contrast, one option for improving emissions trading mechanisms would be to *reduce* their scope. Currently, emissions trading mechanisms may include estimation methodologies with varying degrees of uncertainty but do not explicitly consider uncertainty or treat it in a standardized fashion. There are two options for improving this situation. The first option, as mentioned, is to reduce the scope of emissions trading mechanisms (by excluding uncertain methodologies) to make them more manageable. The second option is to retain the scope of emissions trading mechanisms but to adopt a standardized approach to estimating uncertainty.

Full Carbon Accounting

Full Carbon Accounting (FCA), meaning the full accounting of all emissions and removals, including all greenhouse gases, is a prerequisite for reducing uncertainties in our understanding of the global climate system.

A verified full carbon accounting, including all sources and sinks of both the technosphere and biosphere considered continuously over time, would allow the research and inventory communities to:

■ present a real picture of emissions and removals at national (continental) scales;

■ avoid ambiguities generated by such terms as "managed biosphere," "base-line activities," "additionality," etc.; and

■ (perhaps most importantly) provide reliable and comprehensive estimates of uncertainties that cannot necessarily be achieved using the current approach under the UNFCCC and Kyoto Protocol, which provide for only partial accounting. It is virtually impossible to estimate the reliability of any system output if only part of the system is considered.

FCA is essential for good science. However, it would be for policymakers to decide how FCA is used, in other words, to decide whether the results of FCA should be used for crediting in the sense of the Kyoto Protocol (i.e., for compliance) or only for "accounting," as is currently done under the UNFCCC.

Full Carbon Accounting is expected to facilitate the reconciliation of two broad accounting approaches: top-down and bottom-up accounting.

While methods of both top-down and bottom-up accounting have improved in recent years, both approaches still have areas of weakness. Investment in research is now urgently needed to tackle these limitations, improve the FCA approach, and hence reduce uncertainties.

What are top-down and bottom-up accounting?

Top-down accounting takes the point of view of the atmosphere. It relies on observations of atmospheric CO_2 concentrations, changes in concentrations, and atmospheric modeling to infer fluxes from land and ocean sources. Bottom-up accounting takes the opposite perspective. It relies on observations of stock changes or fluxes at the Earth's surface and infers the change in the atmosphere. Full carbon accounting—estimating all land-based fluxes, whether human-induced or not—is necessary to reconcile the top-down and bottom-up approaches.

Uncertainty in the land-use, land-use change, and forestry sector

Expressing uncertainties in the land-use, land-use change, and forestry sector can be challenging because of:

■ the complexities and scales of the systems being modeled;

■ the fact that human activity in a given year can impact emissions and removals in these systems over several years, not just the year in which the activity took place; and

■ these systems being strongly affected by inter-annual, decadal, and long-term variability in climate.

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Knowledge of the temporal dynamics of systems—what has happened in the past, and how actions in the present will affect emissions/removals in the future—is important; gaps in this knowledge add to uncertainties about the immediate impacts of human activities.

Approaches to estimating emissions and removals in the LULUCF sector frequently involve the use of detailed data and computer models to simulate the complex functional relationships that exist in natural systems. But one consequence of using more detailed methods is that the estimation of uncertainty also comes more into play. However, despite conceptual and technical challenges, powerful tools for combining different kinds of information from multiple sources are becoming available and are increasingly being used by modelers to reduce uncertainties in the LULUCF sector.

These tools allow modelers to increase their focus on model validation and on reconciling results from alternative approaches. However, one key barrier remains. Reporting under the UNFCCC and Kyoto Protocol provides only a partial account of what is happening in the LULUCF sector. To close the validation loop would require the adoption of Full Carbon Accounting.

Despite improvements in approaches to estimating uncertainty in emissions and removals in the LULUCF sector, some challenges remain. The treatment of this sector in future policy regimes requires special consideration.

Pricing uncertainty

Uncertainty is an inherent part of any emissions accounting and it will play an important role in both the scientific understanding of emissions and in their political treatment.

At present, however, uncertainty does not play a role in trading of emissions credits. Ultimately, uncertainty can be borne by either the buyer or seller of any asset, and it should be agreed in advance of any exchange how this is to be dealt with. Risky or uncertain assets will be traded at a discount to the extent that the risk and uncertainty are to be assumed by the buyer.

Literature on the treatment of upfront scientific uncertainty in financial markets is already emerging, but this has not yet been applied to greenhouse gas emissions credits. For now it appears that buyers of emissions credits generally accept credits without uncertainty and the seller is obligated to ensure that the credits are fulfilled.

With the current system of trading in credits, it is not rational for either buyer or seller to work to reduce the uncertainty of emissions estimates if there is a possibility that reducing the uncertainty will reduce the midpoint of the emissions estimate. Given the nature of financial markets, a price mechanism might be better able to deal with the uncertainty of credits than the current cap-and-trade system.

Conclusions

- Uncertainty analysis helps to understand uncertainties: better science helps to reduce them.
- Better science requires the adoption of Full Carbon Accounting. More investment in research is needed to reconcile the bottom-up/top-down accounting approaches which are fundamental to Full Carbon Accounting.
- Some greenhouse gas emissions and removals estimates are more uncertain than others. Options exist to address this issue, and these could be incorporated in the design of future policy regimes.

Further information

The information contained in this briefing is from the Second International Workshop on Uncertainty in Greenhouse Gas Inventories, held at IIASA, 27–28 September 2007. Here, researchers, inventory compilers, and policy experts met to discuss the state of the art in dealing with uncertainty and identifying areas requiring further research. This briefing was coordinated by Thomas M. White with input from workshop participants. Further information is available at: www.ibspan.waw.pl/ghg2007

The Workshop was organized jointly by IIASA and the Systems Research Institute, Polish Academy of Sciences, with sponsorship from the City of Vienna, Cultural Department—Science and Research Promotion, and the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management.

The briefing draws also on the content of the First International Workshop on Uncertainty in Greenhouse Gas Inventories, held in September, 2004, in Warsaw, Poland. The research is presented in the book, *Accounting for Climate Change* (2007) edited by Daniel Lieberman, Matthias Jonas, Zbigniew Nahorski, and Sten Nilsson, and published by Springer.

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