International Experience with Quantifying the Co-Benefits of Energy Efficiency and Greenhouse Gas Mitigation Programs and Policies

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Executive Summary

Improving the efficiency of energy production and consumption and switching to lower carbon energy sources can significantly decrease carbon dioxide (CO_2) emissions and reduce climate change impacts. A growing body of research has found that these measures can also directly mitigate many non-climate change related human health hazards and environmental damage. Positive impacts of policies and programs that occur in addition to the intended primary policy goal are called co-benefits. Policy analysis relies on forecasting and comparing the costs of policy and program implementation and the benefits that accrue to society from implementation. GHG reduction and energy efficiency policies and programs face political resistance in part because of the difficulty of quantifying their benefits. On the one hand, climate change mitigation policy benefits are often global, long-term, and subject to large uncertainties, and subsidized energy pricing can reduce the direct monetary benefits of energy efficiency policies to below their cost. On the other hand, the co-benefits that accrue from these efforts' resultant reductions in conventional air pollution (such as improved health, agricultural productivity, reduced damage to infrastructure, and local ecosystem improvements) are generally near term, local, and more certain than climate change mitigation benefits and larger than the monetary value of energy savings. The incorporation of co-benefits into energy efficiency and climate mitigation policy and program analysis therefore might significantly increase the uptake of these policies. Faster policy uptake is especially important in developing countries because ongoing development efforts that do not consider co-benefits may lock in suboptimal technologies and infrastructure and result in high costs in future years.

Over the past two decades, studies have repeatedly documented that non-climate change related benefits of energy efficiency and fuel conversion efforts, as a part of GHG mitigation strategies, can be from between 30% to over 100% of the costs of such policies and programs strategies. Policy makers around the world are increasingly interested in including both GHG and non-GHG impacts in analyses of energy efficiency and fuel switching policies and programs and a set of methodologies has matured from the efforts of early moving jurisdictions such as the European Union, the United States, and Japan.

1. General Steps for Quantifying Co-benefits

There are four general steps for quantifying the co-benefits of energy efficiency and GHG emissions reduction policies discussed in this report:

1. Calculating emissions differences between base case and alternative policy scenarios.
2. Applying air dispersion modeling or simplifications to characterize and compare concentrations of pollutants.
3. Estimating impacts for each scenario and comparing them against each other (using, for example, population-adjusted C-R functions to find health impacts).
4. Monetizing or otherwise quantifying those impacts in relation to the costs of the alternative policy scenario with care to evaluate those costs according to specific pollutants.

2. Co-benefit Models, Guidebooks, and Applied Studies

Generally, co-benefit quantification efforts are classified into three categories: (1) co-benefit models, (2) ex-ante policy assessment methods, and (3) frameworks established by academics looking to improve the field and apply co-benefits to a broader range of geographies, policies, and programs. Table ES-1 shows a summary of some of the major models, guidebooks, and frameworks for co-benefit quantification.

3. Mitigating Uncertainty and Simplification Methods

Co-benefits theory and research is still evolving and even the most advanced studies are still limited in many ways. Substantial uncertainty is introduced in the creation of the models used to forecast energy and emissions growth as energy demand growth and economic change can be affected by a larger number of variables and forecasting both are inexact sciences. Data validity is also a major source of uncertainty, especially in situations when epidemiological data is applied to areas different from the location of data collection. Uncertainty is a familiar obstacle to policymakers, however, and uncertainties within co-benefit studies should not prevent the further development and application of co-benefits analysis. Sensitivity analysis is a key strategy to detail and examine sources of uncertainty and should be incorporated into any co-benefits research.

Furthermore, several methods for simplifying co-benefits analysis have proven useful in the context of developing countries. Qualitative impact evaluations based on predetermined scoring metrics enable initial evaluations of potential co-benefits and allow researchers to determine priority issues to target with quantitative methods. Quantitative efforts can be simplified by replacing atmospheric dispersion models with simplified linear equations and metrics such as intake fractions, although caution is warranted as this can dramatically reduce output accuracy and transparency. Several methods can also be applied to limit the scope of research, such as limiting the geographic area of the analysis to high-priority areas (such as major metropolitan areas), using wider-scale modeling resolution to find average impacts over larger areas, exclusively focusing on high-priority pollutants such as PM_{10} and $PM_{2.5}$, reducing the detail of population characterizations and reducing the number and types of populations examined (for example, by focusing exclusively on adult, rather than child or elderly, populations and treating populations as homogenous), and using rules of thumb for complex sectors such as transportation. The number of impacts examined is also often a source of simplification; rather than attempt to calculate and monetize highly uncertain impacts to eco-system services and less-empirically proven health impacts, co-benefit analyses will often concentrate on only the most well-known impacts to human health that have been thoroughly documented by epidemiological studies. A best practice in this area is the development of databases that contain all relevant epidemiological data relevant to the jurisdiction. Locally-relevant models that focus exclusively on high-priority sectors and technologies and apply rules of thumb, default values, and locally-relevant monetization metrics have been developed in some areas, although more experienced jurisdictions will benefit from current efforts to expand international best-practice modeling suites such as GAINS for application in certain developing countries (for example, China and India). Furthermore, the development of nationally-applicable guidebooks, as undertaken in recent years by the United States and Japan, works to standardize co-benefit research for application to national-level policies and standardize outputs to allow comparisons between studies.

Finally, controversy surrounds the monetization of impacts and many simplification methodologies may result in highly different research outputs depending on their application. The relatively newer methodology of quantifying health impacts in Disability-Adjusted Life Years (DALYs) and Quality-Adjusted Life Years (QALYs) holds promise to dispose of the monetization controversy and replace it with a uniform, globally-comparable impact assessment methodology. Several methods for simplifying co-benefits calculations appear relevant to the Chinese context as well as other developing countries. However, most simplification methods require considerable up-front standardization efforts to ensure that simplification does not result in inaccuracy and conflicts between research outputs.

Table ES-1. Summary of some of the major models, guidebooks, and frameworks for co-benefit quantification

Name of the Model, Guidebook, or Study	Category	Air Pollutants Modeled	Modeling Steps
The Greenhouse Gas-Air Pollution Interactions and Synergies (GAINS) Model	Model	Sulfur dioxide (SO_2), nitrous oxides (NO_x), ammonia (NH_3), volatile organic pollutants (VOCs), total suspended particles (TSPs), particulate matter (PM_{10}, and $PM_{2.5}$), carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), and the three F-gases (sulfur hexafluoride (SF_6), hydrofloourocarbons (HFCs), and perfluorocarbons (PFCs).	1. Top-down model estimates air pollution emitting activities; 2. User chooses from among pollution control technologies, energy conservation, and fuel switching measures to project emissions levels given user-chosen limiting factors; 3. Atmospheric dispersion model applied to resultant emissions to find new concentrations; 4. Several impacts modeled, including reductions in negative impacts on human health via the exposure of fine particles and ground-level ozone, reductions in damage to vegetation via excess deposition of acidifying and eutrophying compounds, and the reduction in the six GHGs considered in the Kyoto Protocol. Human health damages are calculated in terms of years of life lost, loss in statistical life, and yearly premature mortality.
Simple Interactive Model for Better Air Quality (SIM-Air)	Model	PM_{10}, $PM_{2.5}$, NO_x, SO_2, VOCs, CO_2.	1. User independently projects emission driving activities; 2. User chooses transportation mode switching, efficiency technology measures, fuel switching, and emission source location shifting measures options and applies in a bottom-up manner; 3. User inputs resultant emissions into external pollutant dispersion model to find new concentrations; 4. Human health impacts and/or exceedances of air pollution limit levels are calculated and health impacts are monetized.
The Integrated Global System's Model (IGSM)	Model	CO, VOCs, $NO_{x.}$ SO_2, NH_3, black carbon, and organic carbon, CO_2, CH_4, N_2O, the three F-gases (SF_6, HFCs, PFCs).	1. Top-down model estimates air pollution emitting activities; 2. User chooses fuel switching, energy efficiency technology measures, pollution control technologies, non-energy technologies, household activity and technology changes, carbon sequestration, and IGCC technologies to project emissions levels given user-chosen limiting factors; 3. Atmospheric dispersion and ocean systems models applied to emissions to find new concentrations; 4. Environmental quality improvements and impacts on primary productivity are modeled. Health impacts are not explicitly modeled.
U.S. EPA's Integrated Environmental Strategies (IES) Program	Ex-ante Assessment Guidebook	CO_2, PM_{10}, $PM_{2.5}$, ozone (O_3), SO_2, CO, NO_x, lead.	1. Emissions are modeled from several methodological choices; 2. User chooses technologies and measures to apply, usually air pollution control technologies or activities in the transportation sector; 3. Air dispersion models or simplified methods applied; 4. Human health impact calculation methods are applied, using local data or transferring impact data from other regions. Monetization may also be applied.

Name of the Model, Guidebook, or Study	Category	Air Pollutants Modeled	Modeling Steps
Japan's Manual for Quantitative Evaluation of Co-Benefits Approach to Climate Change Projects	Ex-ante Assessment Guidebook	SO_x, NO_x, soot and dust, CO_2.	1. User given choice of evaluating impacts on qualitative or quantitative basis; 2. For quantitative analysis, user applies formulas following several data input requirements, choosing from several technology and activity change options; 3. Air, water, and waste pollution measures output by model, without further dispersion modeling or quantification of impacts.
Gold Standard Program Model	Ex-ante Assessment Guidebook	NO_x, SO_x, lead, carbon monoxide (CO), O_3, persistent organic pollutants (POPs), mercury (Hg), Chlorofluorocarbons (CFCs), halogens, respirable suspended particulate matter (RSPM), NH_3, PM_{10}, VOCs, TSP, dust, odors.	1. CDM project developers meeting certain technology and activity (renewable energy, energy efficiency, or waste handling) requirements create a project account with the Gold Standard Program Registry; 2. Project developers work with local communities to define community goals according to several possible impact metrics; 3. After approval by the Registry, project developers develop baseline and impact calculations using program guidance; 4. Project developers establish monitoring systems for chosen metrics and after project is approved by local community and third-party auditor, project receives certification by Registry.
Mainstreaming Transport Co-benefits Approach: a Guide to Evaluating Transport Policies	Ex-ante Assessment Guidebook	NO_x, PM, CO, CO_2	1. User is presented with bottom-up model equations regarding several co-benefits of implementing transportation-related technology, fuel switching, and activity (e.g. mode switching measures); 2. Rules-of-thumb or user-generated data is input into equations based on the expected level of implementation of selected measures to find resultant emissions and activity changes; 3. User applies simplified impact quantification formulas to find impacts.
The ClimateCost Project	Ex-ante Assessment Applied Study	SO_2, NO_x, VOCs, NH_3, $PM_{2.5}$	1. Emissions driver activities are forecast using the top-down GAINS model; 2. Technologies and measures such as energy efficiency-oriented technological changes, fuel switching, and conventional pollution control technologies applied in line with existing non-GHG pollution and energy use abatement regulations; 3. Atmospheric dispersion model applied; 4. Impacts on human health, physical infrastructure, and agricultural primary productivity are output and monetized.
Analysis conducted for the European Environmental Agency (EEA) regarding air quality co-benefits of GHGs mitigation policies	Ex-ante Assessment Applied Study	NO_x, SO_2, PM_{10}, $PM_{2.5}$, CO_2, CH_4, N_2O, the three F-gases (SF_6, HFCs, PFCs), NH_3, non-methane VOCs (NMVOC)	1. Drivers of emissions are forecast using a top-down model; 2. A bottom-up methodology is used to project emissions changes given carbon dioxide emissions limits, the implementation of maximum feasible technologies, and the continuation of air pollution control technologies; 3. An air pollution dispersion model is applied to find new concentrations; 4. Impacts of each scenario are given in human health, vegetation damage area, area of forests damaged by acidification, and area of land damaged by eutrophication. Health impacts are monetized.

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ExternE Projects Model	Ex-ante Assessment Applied Study	SO_2, NO_x, PM_{10}, $PM_{2.5}$ NMVOCs, NH_3, certain heavy metals, CO_2, CH_4, N_2O, the three F-gases (SF_6, HFCs, PFCs)	1. Energy demand forecasts are given by IPCC projections; 2. User chooses fuel mix to meet energy demand based primarily on fuel switching measures; 3. Atmospheric, soil, and water pollution dispersion models are applied; 4. Health, agriculture production, silviaculture production, global warming, and other harms are quantified, and health, agriculture, physical infrastructure costs, and some climate change and eco-system damage related impacts are monetized.
Hidden Cost of Energy	Academic Framework	SO_2, NO_x, $PM_{2.5}$, PM_{10}.	1. Current energy production practices in four sectors are modeled based on current energy demands and compared against each other; 2. Plant-level and source emissions are calculated based on fuel mix; 3. Emissions are analyzed using an atmospheric dispersion model; 4. Impacts are assessed for human health, grain crop and timber yields, building materials, recreation, visibility, eco-system services, and climate change impacts.
The Co-benefits of Greenhouse Gas Mitigation Policies in China model	Academic Framework	PM, SO_2, NO_x, CO_2	1. A hybrid modeling approach is used to predict energy demand and changes in energy demand given costs of electricity production practices to meet policy goals; 2. Resultant emissions for scenarios are based on technologies applied given model's explicit price constraints; 3. An atmospheric dispersion model is applied to resultant emissions; 4. Intake fractions are used to find health damages and impacts are monetized.
Resources for the Future's model of U.S. electricity generation sector carbon policy co-benefits	Academic Framework	NO_x, SO_2	1. A top-down model is applied to find electricity demand; 2. Changes in emissions found based on fuel switching and electricity production efficiency technologies implemented based on carbon price expectations and meeting requirements of other pollution regulations; 3. An atmospheric dispersion model is applied to find changes in pollutant concentrations; 4. Human health impacts are modeled and monetized; other impacts include reduced costs of implementing convention pollution control technologies.

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