Energy solutions for a changing world

Climate-Friendly Air Quality Management

Strategies for Co-Control

Authors

Chris James and Rebecca Schultz

November 2011

Global
US
China
EU

The Regulatory Assistance Project

Home Office (US)
50 State Street, Suite 3
Montpelier, Vermont 05602

phone: 802-223-8199
fax: 802-223-8172

www.raponline.org

Table of Contents

RAP

Executive Summary

Climate-friendly air quality management refers to techniques, policies, and regulations that promote concurrent reductions of criteria and toxic pollutants and greenhouse gas (GHG) emissions.[1] Recent studies have shown that significant benefits can be achieved through integrating climate change mitigation and air quality improvement efforts.[2] According to one study, these benefits may amount to additional CO_2 reductions of 15% in Western Europe and 20% in China.[3] A combined policy scenario for China in which GHG mitigation measures, such as energy efficiency, cogeneration, and renewable electricity generation, are used to meet air quality objectives may achieve those goals at an estimated 60% of the cost of using end-of-pipe air quality measures exclusively, while also reducing CO_2 emissions by 9%.[4] Similar analysis for the European Union (EU) has shown that "co-control" can decrease the costs of local air pollution reductions so as to pay for as much as 40% of the cost of GHG mitigation.[5] Control measures that address only local air quality will likely lead to increased GHGs and maintain high GHG emissions for decades. This is because sulfur dioxide (SO_2) and nitrogen oxide (NO_X) are controlled through end-of-pipe (or "smokestack") technologies, which, because they require additional electricity to operate, reduce plant efficiency and increase GHG emissions.[6] Conversely,

---

[1] Criteria pollutants include: sulfur oxides, nitrogen oxides, carbon monoxide, particulate, and ozone. Toxic pollutants include but are not limited to: metals, such as lead and mercury; volatile organic compounds (VOC), such as toluene, benzene, and xylene; and polycyclic aromatic hydrocarbons (PAHs). We recognize that the term "criteria pollutants" has a particular meaning in the United States. Here, we use the term more broadly to apply to those pollutants for which an air quality standard has been established by any country.

[2] The term "air quality" refers broadly to pollutants, and the policies to control them, that contribute to the condition of the atmosphere and its impacts on public health in a particular region. Although these pollutants may also have climate-change impacts, they are not the major greenhouse gases (GHGs), and historically have been distinguished from GHGs for regulatory purposes. We follow that naming convention here. Indeed, it is the purpose of this paper to show how the actions to reduce local and GHG emissions can be combined and integrated to achieve better outcomes at lower overall cost: thus the new term "climate-friendly air quality management."

[3] J. Bollen et al. Local Air Pollution and Global Climate Change: A Combined Cost-Benefit Analysis, *Resource and Energy Economics,* v. 31, 2009, pp. 161-181.

[4] UNDP China Human Development Report 2009/2010. China and a Sustainable Future: Towards a Low Carbon Economy & Society. Available online at http://hdr.undp.org/en/reports/nationalreports/asiathepacific/china/nhdr_China_2010_en.pdf.

[5] Markus Amann et al. GAINS ASIA: Scenarios for Cost-Effective Control of Air Pollution and Greenhouse Gas Emissions in China. International Institute for Applied Systems Analysis and the Energy Research Institute, November 2008. Markus Amann et al. Cost-Effective Emissions Reductions to Meet the Environmental Targets of the Thematic Strategy Under Different Greenhouse Gas Constraints, 2007. Available online at http://www.iiasa.ac.at/rains/CAFE_files/NEC5-v1.pdf. Markus Amann et al. Potential and Costs For Greenhouse Gas Mitigation in Annex 1 Countries. Interim Report, November 2009. Available online at http://www.iiasa.ac.at/Admin/PUB/Documents/IR-09-043.pdf.

[6] On average, NO_X and SO_2 controls can reduce power plant efficiency by 2%. W.H.J. Graus and E.

because currently there are no smokestack technologies to remove GHG emissions, it is only through thermal and end-use efficiency improvements, fuel-switching, and changes in the overall resource portfolio that reductions in CO_2 and other gases can be achieved. It is also the case that, when efficiency is improved, emissions of criteria pollutants also decrease.[7]

A comprehensive assessment of climate-friendly air quality measures adopted in China, the EU, and the United States concludes that, to be successful, five conditions must be met. They are:

- The institution of an open and multidisciplinary planning process to evaluate potential policies and determine cooperative strategies for achieving goals and, in particular, the establishment of a firm foundation of cooperation between energy and environmental regulators;
- The adoption of initial benchmarks based on the best information available at the time;
- The establishment of mechanisms for continuous evaluation and assessment and revisions as appropriate;
- Adequate and sustained agency resources, with opportunities for training and professional development; and
- The implementation of policies that transcend their champions—that is, policies that do not depend on their original designers and supporters to remain in place.

On May 11, 2010, the General Office of the State Council approved the Ministry of Environmental Protection's (MEP) regional air quality management rule (RAQM). The State Council circular on *Joint Prevention and Control of Air Pollution to Promote Regional Air Quality* (国办发[2010]33号) and MEP's subsequent *Guidelines for 12th Five-Year Plans for Air Pollution Joint Prevention and Control in Key Regions* (环办[2010]153号) demonstrate a clear adherence to the principles of climate-friendly air quality management. The RAQM rule initially focuses on nine key regions, including Beijing-Tianjin-Hebei, the Yangtze River Delta, the Pearl River Delta, and six city-clusters consisting of the areas around Shenyang, Changsha, Wuhan, Chengdu-Chongqing, the Shandong peninsula, and the coastal area across the straits from Taiwan.[8] Plans developed for these areas will enable shared energy and air quality objectives to be achieved, and the lessons from the implementation of the RAQM rule can be adapted more broadly to other provinces and municipalities in China, as well as globally to the EU and United States.

Climate-friendly air quality management in the EU and United States offers several lessons too. For their own historical

Worrell. Effects of SO_2 and NO_X Controls on Energy-Efficiency Power Generation. Energy Policy 35 (2007).

[7] This last point is almost always true, but there are exceptions. In certain applications, both combustion efficiency and NO_X emissions are functions of combustion temperature, but both are not optimized at the *same* combustion temperature. There is a trade-off therefore between NO_X and CO_2 emissions in such cases. This only reinforces, however, the need for a multi-pollutant strategy, because only then will challenges of this kind be addressed head on and the most effective, least costly solutions found.

[8] A translated version of the RAQM rule is found at http://www.chinafaqs.org/library/chinas-new-regional-air-quality-regulation-translated.

reasons, however, US and EU government structures are not well coordinated to jointly address comprehensive energy and environmental needs. Elements of China's RAQM rule could therefore serve as examples for governments in the EU and United States to adopt, as agencies in these countries continue to make progress at reducing pollution and developing their energy efficiency and renewable energy resources.

A foundation of climate-friendly air quality management is the coordination of environmental and energy policy-making. Integrated policies can save money and time while reducing pollution, and can improve the reliability of electricity service while minimizing unintended consequences.

Shifting to regulation through a multi-pollutant approach will require institutional, policy, and technical changes. From our review of international experience, we conclude that the most important lessons for China are:

Institutional. Although it is important for air and utility regulators to coordinate their respective long-term plans, even more critical is the need for air regulators to develop power sector expertise that transcends their traditional knowledge of boiler design and operation. As utility regulators discuss the next steps in power sector structure and topics such as regional transmission plans, the participation of air regulators in these exercises will expose how inextricably linked environmental and energy policies are, will reveal how poor policy design in one arena will have deleterious effects in the other (will show, for example, how energy policies such as renewable portfolio standards and energy efficiency resource standards are also environmental policies), and will help air regulators consider a variety of policy measures that could be more cost-effective than solely relying on end-of-pipe technologies to reduce emissions. Government institutions can be designed to enable this cross-fertilization and ultimately create stronger and more effective regimes for clean air and low carbon growth.

Policy. The most effective policies are those that affect the root causes of emissions rather than deal with them solely through control efforts at the smokestack. Affecting the root causes of emissions pushes the point of regulation farther upstream away from the smokestack, to influence how energy is made and how it is consumed. Incorporating energy efficiency, renewables, and less polluting coal-fired generation technologies into air regulatory practices is a good starting point. Innovative financing instruments have also been developed, such as the "recycling" of pollution permit revenues into energy efficiency and renewable energy programs. There are all kinds of policy solutions across an array of sectors that demonstrate reducing local air pollution and global climate change emissions can be done simultaneously and cost-effectively.

Technical. More recently, the United States and Europe have adopted integrated multi-pollutant approaches that address pollutants that the authorities want to control now and expect to control in the future. Such programs target, for example, particulate matter (PM), NO_X, SO_2, mercury, and, increasingly, CO_2. By setting goals for a broad range of pollutants, these approaches encourage industry to develop long-term financial and environmental plans to optimize investment in and configuration of pollution control equipment. This is a primary objective of multi-pollutant strategies. Such an approach offers better planning, greater certainty, lower costs, and more environmental benefits per dollar invested.[9] Such approaches also require technical knowledge about how reductions of one pollutant will affect other pollutants, both from the perspective of government planning and that of enterprises.

[9] For resources related to the US Environmental Protection Agency's (EPA) multi-pollutant analyses and technical supporting documents, see http://www.epa.gov/airmarkets/progsregs/cair/multi.html. Also see, Sam Napolitano et al. A Multi-Pollutant Strategy. *Public Utilities Fortnightly*, January 2009, available at http://www.epa.gov/airmarket/resource/docs/multipstrategy.pdf.

1. Introduction

Climate change and air pollution are closely interconnected problems, yet more often than not they are considered in isolation. Governments around the world, poor and rich, have sought to address these challenges through distinct technology and policy solutions, often executed and enforced by separate government agencies, under different legal frameworks. But these problems, caused as they are in large part by current patterns of energy consumption and production, are altogether interrelated, and techniques developed to control one category of emissions will usually have impacts on the other.[10] There are substantial benefits to assessing the impacts of and designing control strategies for the two environmental challenges in an integrated fashion.

Recent studies from around the world demonstrate that significant cost-effective and synergistic benefits can result from implementing measures that jointly reduce local air pollution and greenhouse gases (GHGs). GHG action plans have potential ancillary benefits, or "co-benefits," for local air quality. This is generally because the structural shifts in the electric, industrial, and transportation sectors that GHG reduction policies drive will also reduce fine particles and other harmful local air pollutants.[11] Importantly, these co-benefits to local air quality accrue over a shorter timeframe than do the climate benefits, and their associated cost-savings—to human health, natural ecology, agriculture, buildings, and other human-made structures—can significantly reduce net costs of climate mitigation.

It is also clear that unnecessary costs are imposed on businesses and society from adoption of environmental policies that have not been designed with their implications for energy use in mind. A pollution control framework that considers both energy and environmental regulation can avoid unintended, adverse consequences. These consequences can range from increased toxic discharges, locking in older technologies that expose industry to increased costs to reduce hazards later, prolonged exposure and public health risks from air contaminants, and missed opportunities for implementing lower-cost solutions today. A coordinated approach can avoid these costs.

Recognizing the linkages between controlling local air pollution and GHGs can help air regulators leverage the political

[10] For evidence of this, consider end-of-pipe technology controls for SO_2 or NO_X. Because this equipment requires an additional electric load to operate, it decreases thermal efficiency and therefore increases greenhouse emissions. Or consider carbon capture and sequestration (CCS) technology to reduce CO_2 emissions from fossil-fuel power plants: to separate, compress, and pump CO_2 emissions into geological formations, CCS can use as much as 20 to 40% of a plant's energy output, thus substantially increasing emissions of criteria pollutants associated with burning additional fossil fuels to meet demand.

[11] Fine particles have well documented public health and environmental impacts. Programs that reduce fine particles include measures that reduce emissions of NO_X and SO_2, as nitrates and sulfates are primary components of fine particles globally.

momentum and financial resources that currently back the low-carbon agenda. An air quality action plan that is designed to simultaneously achieve significant reductions in GHGs can contribute to meeting climate change goals, such as China's own 40 to 45% carbon intensity reduction target, can offer more benefit to the broader society, and can stand to garner greater support across government agencies and sectors.

Scientists and public health officials have long observed the adverse effects, both direct and indirect, on public health from industrial production and other uses of fossil fuels, but the costs of these effects have traditionally not been included in the economic analysis or regulatory review of such activities. Several recent developments highlight how these "external" costs and benefits can be monetized (i.e., quantified in economic terms) and incorporated into regulatory processes. These include:

- Research showing that for each $1 invested in end-use energy efficiency, there are direct savings of $3 to $4 through reduced energy consumption[12], as well as additional benefits in reduced public health costs and impacts.[13]
- Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) modeling completed as part of the US Environmental Protection Agency's (EPA's) Integrated Environmental Strategies (IES) for several countries including Brazil, India, and Mexico shows that thousands of premature deaths can be avoided and that much of the costs to implement GHG and criteria pollutant reduction policies can be offset by reduced medical expenses alone.[14]
- Legislation in some US states that requires inclusion of environmental externalities in utility integrated resource plans (IRP).[15]
- The National Academy of Sciences report that quantifies the public health costs of fossil-fuel combustion.[16]

Development of models that analyze combinations of policies and the trajectories of their implementation has enabled agencies to consider the potential effects of new requirements before they are implemented. This prevents adoption of policies that are more costly or that may impose constraints on electricity reliability, and it facilitates the creation of complementary programs to cover multiple

[12] An average number, but for example see "Connecticut's Investment in Energy Efficiency: 2010 Report of the Energy Efficiency Board," March 1, 2011, found at http://www.ctsavesenergy.org/files/2010%20Annual%20Legislative%20Report%20Final.pdf

[13] From BENMap analysis of pollutant reductions driven by energy efficiency. See for example "Breathing Better: Linking Energy and GHG Reductions to Health Benefits in China," by Kong Chiu et al, Woodrow Wilson International Center for Scholars, China Environment Series 2007, pp. 117-122.

[14] US EPA, Integrated Environmental Strategies, available at www.epa.gov/ies. EPA's Integrated Environmental Strategies Handbook is available at http://www.epa.gov/ies/pdf/handbook/ies_comp_screen.pdf

[15] Order 7661, September 22, 2009, by the Delaware Public Service Commission, directing Delmarva Power and Light to include environmental externalities into its Integrated Resource Plan, and to monetize those costs and benefits. Available at http://depsc.delaware.gov/orders/7661.pdf. Utah and Arizona are among other states now requiring utilities to address externalities in their IRP.

[16] National Academies Press. Hidden Costs of Energy, Unpriced Consequences of Energy Production and Use. 2010. Available at http://www.nap.edu/openbook.php?record_id=12794&page=161.

pollutants. One analytical model, which was designed to analyze air quality improvement and GHG reductions, generates outputs that are fed into a second model, an economic model that determines the cost of each policy and its potential effects on labor. Outputs from a third model, focused on the energy sector, are used to assess potential environmental effects and vice versa.[17] An iterative institutional process is developed to allow modeling results to inform agency decisions.

The number of modeling platforms continues to expand, but among the most commonly used today are GAINS[18] and MARKAL.[19] Monte Carlo probabilistic analyses have also been used to monetize benefits, such as the recently undertaken evaluation of co-benefits of energy efficiency and renewable energy in the state of Utah.[20]

So what is climate-friendly air quality management? Why is it beneficial? What are the most effective applications of these kinds of policies around the world? The purpose of this paper is to answer these questions and present a range of information and policy options to help local, regional, and central-level air quality planners in China to implement the May 2010 RAQM rule.

Section 2 will define climate-friendly air quality management and describe the institutional, policy, and technical considerations that inform the joint control and prevention of local air pollution and GHG emissions.

Section 3 will describe international experience with climate friendly air quality management, with a particular emphasis on examples from the United States. We will also give an overview of recent research and analysis on climate-friendly air quality management. As few jurisdictions globally have completed true "climate-friendly" plans; examples of best practices, with data, help to show the degree of emissions benefits that can be achieved and their timeframe.

Section 4 will then more closely examine institutional arrangements to facilitate cross-sector management of GHG emissions and local air pollution. From the lessons from global co-control efforts, this section derives the core principles and components needed to develop and implement a comprehensive climate-friendly air quality management plan. We describe policy practices from across a range of relevant sectors that have been proven to effectively control GHGs and local air pollution. Section 6 will provide the technical tools to

---

[17] ICF, International, Integrated Planning Model (IPM), http://www.epa.gov/airmarkets/progsregs/epa-ipm/docs/v410/Chapter2.pdf

[18] Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) modeling platform was developed by the EU, used in China and India: http://gains.iiasa.ac.at/gains/reports/GAINS-Asia-Methodology-20081205.pdf

[19] MARKet ALlocation (MARKAL) model was originally developed by Energy Technology Systems Analysis Program (ETSAP) of the International Energy Agency: http://www.etsap.org/markal/main.html.

[20] Fisher, Jeremy PhD et al. CoBenefits of Energy Efficiency and Renewable Energy in Utah. Synapse Energy Economics, March 24, 2010. The report's analysis reflected that each year, fossil generation consumes 24 billion gallons of water and results in 202 premature deaths and over 150 additional hospital visits, with estimated external costs of $36 to $43 per MWh, or about the same as the direct costs of conventional electricity generation.

facilitate climate-friendly air quality management. Thanks to efforts by organizations such as the International Institute for Applied Systems Analysis (IIASA) and the US EPA, comprehensive and integrated modeling frameworks have been developed recently to enable air quality agencies to analyze the environmental, energy, and economic effects of policy measures that they are considering. Completing such an analysis prior to implementing policies helps air agencies test policy ideas, prepare briefings for decision makers, and prioritize which policies to first implement (or to discard) based on their characteristics, degree of benefits, and influences on energy systems or economics.

2. A Harmonized Approach to Controlling Local Air Pollution and Greenhouse Gases

Making the case for a harmonized approach to controlling criteria and GHG emissions builds on experience demonstrating that developing separate control strategies for each pollutant of concern is *not* the most effective—or cost-effective—way to reduce pollution.[21]

2.1 Climate-friendly air quality management is a multi-pollutant control strategy.

Emissions control policies have traditionally focused on one pollutant at a time, forcing power plants and other industrial facilities to develop separate control strategies for each pollutant. A single-pollutant approach can be very effective for the pollutant of concern. Instruments such as continuous emissions monitoring systems (CEMS) facilitate precise determination of compliance with regulatory standards. Single-pollutant strategies, however, can inadvertently cause emissions of other pollutants to increase and can lead to higher overall costs of compliance.[22]

Adverse health effects and other environmental problems are caused by more than one pollutant, usually by interactions among several.[23] As a result, single-pollutant approaches often fail to achieve overarching environmental or public health goals, such as reducing water bodies' acidification or reducing excessive morbidity and mortality from respiratory illness. Controlling one pollutant can fail to address a particular problem and may even make the problem worse, as in the case of reducing NO_X, which can in some circumstances actually increase ozone (O_3), the third most powerful GHG (after CO_2 and methane).

Single-pollutant approaches also tend to waste resources (e.g., fuel, steel) and cost more for industry, government, and society than an integrated, multi-pollutant approach. Whether regulations apply to power sector emitters or industrial emitters

[21] The National Academy of Sciences found in its 2004 review that the use of individual pollutant-by-pollutant control strategies failed to take into account interactions between pollutants and pollution control technologies and failed to achieve air quality improvements cost-effectively. It recommended instead that control measures can be optimized if the full range of pollutants and control options are considered through an integrated and comprehensive strategy. Air Quality Management in the United States, National Academy of Sciences, 2004. Available at http://www.nap.edu/catalog.php?record_id=10728.

[22] For example, most pollution controls have an associated heat-rate penalty (i.e., they require more fuel to power the equipment). As a result, other emissions that are not reduced by the control may increase. An SO_2 scrubber will often result in additional NO_X and CO_2 emissions (approximately a 1.7% increase). Another example is the Selective Catalytic Reduction (SCR) technique to control NO_X, which can lead to increased SO_3 emissions, which combine with water to form sulfuric acid.

[23] Examples of combined pollutants causing environmental problems include: VOCs and NO_X, which contribute to O_3; SO_2 and NO_X, which contribute to acid rain; and SO_2, NO_X, black carbon, etc., which contribute to $PM_{2.5}$.

more broadly, a multi-pollutant approach encourages the affected industry to develop long-term compliance strategies to optimize pollution control options. And it can also drive early resource choices toward those with lower environmental impacts.

Also, policies that successfully decrease peak concentrations of NO_X, SO_2, or PM may be ineffective at reducing such concentrations when measured over longer time frames. Indeed, the focus on peak or short-term periods may be contributing to broad global dispersion of pollutants. Global background concentrations of ozone are increasing,[24] as measured at several locations considered to be otherwise free from anthropogenic influences. Broad dispersal of mercury has also been observed.[25] Fine particulate pollutants ($PM_{2.5}$) transported from Asia are now believed to contribute approximately one quarter of the ambient $PM_{2.5}$ concentrations in Los Angeles and other locations along the US Pacific Coast.[26] The increase in concentrations and the pollutant dispersal are important factors that affect public health and limit the efficacy of local air pollution control measures.

Regulators have started to address criteria pollutants through multi-pollutant planning. Some emissions such as CO_2, soot, and ozone play a role in climate warming, whereas others such as sulfates from SO_X emissions play a role in climate cooling. Measures to reduce air pollution thus may help mitigate—or exacerbate—climate change. Similar coordinated planning approaches need to be taken to integrate GHGs into air quality control measures. Adopting these approaches around the world has been slower than those for criteria pollutants; only a handful of jurisdictions have begun to apply this sort of holistic approach to the problem of climate change (see the following section).

Shifting to a multi-pollutant approach will require institutional, policy, and technical changes. We provide examples of each.

2.1.1 Institutional. Although it is important for air and utility regulators to coordinate their respective long-term plans, even more critical is the need for air regulators to develop power sector expertise that transcends their knowledge of boiler design and operation. As utility regulators develop the next steps in electricity market design and address topics such as regional transmission planning, air regulator participation in these exercises would help promote consistent assumptions regarding future environmental regulations, help air regulators understand how energy policies such as renewable portfolio standards and energy efficiency resource standards are also environmental policies, and help air

[24] D.D. Parrish, D.B. Millet, and A.H. Goldstein. Increasing Ozone Concentrations in Marine Boundary Layer Air Inflow at the West Coasts of North America and Europe. Atmospheric Chemistry and Physics Discussions, 22 July 2008, v. 8, pp. 13847-13901. Available at http://www.atmos-chem-phys-discuss.net/8/13847/2008/acpd-8-13847-2008.pdf. Douw Steyn, "The Globalization of Smog, presentation to Ontario Ministry of Environment," Learning Forum on Emerging Issues in Air Quality, 12-13 May 2009, Toronto, Canada.

[25] United Nations Environment Programme, Global Mercury Assessmente, December 2002. Available at http://www.chem.unep.ch/mercury/report/Final%20report/final-assessment-report-25nov02.pdf

[26] "Asian Ozone Raising Levels of Smog in Western United States, Study Shows," Associated Press, 21 January 2010. Available at http://www.guardian.co.uk/environment/2010/jan/21/ozone-united-states-asian-pollution.

regulators to consider a variety of policy measures that could be more cost-effective than solely relying on end-of-pipe technologies to reduce emissions.

Air and utility regulators in the northeastern United States have collaborated on many joint planning efforts since the late 1990s. These include:

1. Efforts to assure adequate reliability and quick response to peak electricity demand through reliance on demand response and distributed generation policies that emphasize clean resources and energy efficiency;
2. Evaluation of how generating resources are displaced by the region's energy efficiency and renewable energy policies, and calculating the emissions benefits of these policies; and
3. Design of forward capacity markets that treat all resources comparably, thereby enabling energy efficiency to compete with generation to meet capacity needs and to receive revenue for providing this service (energy efficiency now provides approximately 5% of the capacity in the New England region, and it has helped to stabilize electricity prices there).

2.1.2 Policy. There are many advantages to policies that, from their initial design through implementation and evaluation, aim to reduce criteria and GHG pollutants. In the United States, developing policies that lead to reductions in both criteria pollutants and GHG emissions began a decade ago when the national association of air pollution regulators (then called STAPPA/ALAPCO) published a handbook for state and local air quality officials.[27] Since then there have been many strong policies adopted and continual improvements in our knowledge of atmospheric chemistry. There have also been improvements in the technical models that assess the costs and benefits of control measures, which have in turn led to new policy advances in recent years.

The integrated frameworks for multi-pollutant regulation that have been adopted in the United States and Europe include pollutants that the authorities want to control now as well as others they expect to control in the future. Such programs (some of which are discussed in greater detail below) target, among others, PM, NO_X, SO_2, mercury, and, increasingly, CO_2. Setting goals for a broad range of pollutants encourages industry to develop long-term financial and environmental plans to optimize investment in and configuration of pollution control equipment. This is a primary objective of multi-pollutant strategies. Such an approach offers better planning, greater certainty, lower costs, and more environmental benefits per dollar invested.[28]

[27] State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials (now the National Association of Clean Air Agencies, or NACAA). Reducing Greenhouse Gases and Air Pollution: A Menu of Harmonized Options. October 1999.

[28] For resources related to the US EPA's multi-pollutant analyses and technical supporting documents, see http://www.epa.gov/airmarkets/progsregs/cair/multi.html. Also see Sam Napolitano et al. A Multi-Pollutant Strategy, *Public Utilities Fortnightly*, January 2009. Available at http://www.epa.gov/airmarket/resource/docs/multipstrategy.pdf

Innovative financing instruments have also been developed, such as the auctions of CO_2 allowances in the US Regional Greenhouse Gas Initiative (RGGI). RGGI raised $494 million during 2009, the first year that GHG allowances were sold.[29] This revenue added 10 to 30% to the energy efficiency and renewable energy programs that the ten northeastern participating states are implementing.[30] In the United Kingdom, the Energy Saving Trust, a climate change initiative, directly assists homeowners and businesses to reduce their energy consumption, which then reduces GHGs and local air pollutants.[31]

2.1.3 Technical. Even if GHG reductions are voluntary, the inclusion of GHG emissions in an air pollution program changes the dynamics of the planning exercise and forces agencies and affected parties to consider multiple means of reducing the criteria pollutants and GHGs simultaneously.

Surprisingly, the costs of combining the efforts may be lower than the costs of a strategy focused on reducing SO_2 and NO_X alone. Control measures that address only local air quality will likely lead to increased GHGs and maintain high GHG emissions for decades. This is because SO_2 and NO_X are controlled through end-of-pipe (or "smokestack") technologies, which, because they require additional energy to operate, reduce plant efficiency and increase GHG emissions.[32] Conversely, because currently there are no smokestack technologies to remove GHG emissions, it is only through thermal and end-use efficiency improvements, fuel-switching, and changes in the overall resource portfolio that reductions in CO_2 and other gases can be achieved. It is also the case that when efficiency is improved, emissions of criteria pollutants also decrease.[33]

Two critical technical areas that require consideration in climate-friendly air quality plans are:

- The models that are used to evaluate the energy, environmental, and economic attributes of policy measures that can be implemented to reduce pollution; and
- The sequencing of emissions control and monitoring equipment installed to capture criteria pollutants and measure effluence concentrations.

Air quality and energy regulators use computer models to assess their future resource needs. The regulators develop scenarios to characterize the baseline, or

[29] Environment Northeast. RGGI At One Year: An Evaluation of the Design and Implementation of the Regional Greenhouse Gas Initiative. February 2010.

[30] The Regulatory Assistance Project. The Regional Greenhouse Gas Initiative in the Northeastern United States: Auctioning Emissions Allowances. November 2008.

[31] More information on the Energy Saving Trust can be found at http://www.energysavingtrust.org.uk/

[32] On average, NO_X and SO_2 controls can reduce power plant efficiency by 2%. W.H.J. Graus and E. Worrell. Effects of SO_2 and NO_X Controls on Energy-Efficiency Power Generation. Energy Policy 35 (2007).

[33] This last point is almost always true, but there are exceptions. In certain applications, both combustion efficiency and NO_X emissions are functions of combustion temperature, but both are not optimized at the *same* combustion temperature. There is a trade-off, therefore, between NO_X and CO_2 emissions in such cases. This only reinforces, however, the need for a multi-pollutant strategy, because only then will challenges of this kind be addressed head on and the most effective, least costly solutions found.

reference case, which typically assumes that policies in effect today will continue to be in effect over the time period analyzed. Then assumptions about possible changes to that reference case are developed, reflecting how air pollution levels and electricity consumption may vary depending upon, among other things, economic growth, changes in fuel prices, and continued progress to reduce pollution levels to maintain compliance with public-health-based air quality standards. As we explain more fully in part two, the choice of which model to use can influence the degree to which decentralized and dispersed policies that improve energy efficiency are accounted for, and the cumulative effects of these resources can be determined.

Emissions control equipment, such as flue gas desulfurization and SCR technologies, provides air quality agencies with effective, enforceable, and reliable pollution reductions. Broad deployment of these technologies has enabled the United States to reduce acid rain and smog-forming emissions by more than two thirds since enactment of the 1990 Amendments to the Clean Air Act. With new, more protective criteria pollutant standards being adopted, however, states and the EPA are now asking whether attainment of future air quality standards might be achieved more cost-effectively and as expeditiously through policy measures that include not only end-of-pipe emissions controls, but also end-use energy efficiency, demand response, and renewable energy resources.

One lesson from the 1990s' experience with emissions controls on power plants is that the companies installing these controls seek to recover their costs through higher electricity rates (as approved by the regulatory authorities) or through higher competitive prices in areas that have restructured their electricity markets. Comparing the costs of emissions controls with data that have been compiled on the cost of saved energy demonstrates that states are accumulating energy savings at costs that are lower than the cost of new generation, and lower than the expected abatement costs to meet future EPA criteria pollutant reduction requirements. According to modeling performed for the Edison Electric Institute[34], the cost to install new emissions controls for NO_X, SO_2, $PM_{2.5}$, and mercury will be in the range of $30 to $35 per MWh. These costs do not include future abatement costs to meet any GHG requirements.

Data on the costs of emissions controls for existing power plants and those on the actual costs of saved energy suggests that a hybrid approach in which all cost-effective energy efficiency programs and new emissions controls both play a role could be equally or more environmentally protective and could result in lower overall program costs. Also, other energy efficiency benefits reduce the quantity of ash disposed into landfills and the quantity of cooling water needed, important considerations in areas where land and water constraints exist.

A climate-friendly air quality policy would therefore include strategies that sequence what emissions controls are installed and how much energy efficiency and renewable energy could be achieved over the time

[34] ICF International, EEI Preliminary Reference Case and Scenario Results, May 21, 2010. This report is labeled confidential, do not quote or cite. However, the report is public since it was released into the U.S. Senate record by Sen. Voinovich.

period needed for that geographic area to meet its environmental objectives, and to sustain future economic growth such that the region's carrying capacity is not exceeded.

The following section discusses programs from around the world that exemplify climate-friendly air quality management and includes an overview of the results of recent research and analysis.

3. Policy Efforts to Address Greenhouse Gases and Air Pollutants

Multi-pollutant strategies that include both GHGs and local air pollution are increasingly being applied in advanced environmental management systems around the world. Below we describe a sample of these programs, both existing programs and new efforts.

3.1 Current Programs

Examples of programs that are currently in effect include the European Commission's National Emissions Ceiling, Massachusetts' Multi-Pollutant Regulation 310 CMR 7.29, North Carolina's Clean Smokestack Act, and New Hampshire's Multi-Pollutant legislation.[35] These multi-pollutant approaches, their scope and coverage, and results to date are described in Table 1.

Each program described in Table 1 requires reporting to assess progress toward achieving the required emissions reduction goals. For example, North Carolina's reports, which compare emissions reductions from the Clean Smokestacks Act with improvements in ozone and fine particle concentrations, document the benefits of the legislation.

It is important to note also that every program has since been modified or expanded in some way: to cover additional pollutants, to require additional emissions reductions, or to be integrated into broader regional emissions reductions programs.

[35] New Hampshire General Court, January 2002, House Bill 284, http://www.gencourt.state.nh.us/legislation/2002/HB0284.html

Location	Description	Results to Date
Massachusetts (MA) (USA)	Multi-Pollutant Regulation (310 CMR 7.29) establishes output-based emissions standards for fossil-fueled power plants (passed in 2001). Standards are 1.5 lbs/MWh NOX, 3 lbs/MWh SO2, 1,800 lbs/MWh plus source-specific cap for CO2 and case by case determination for mercury. MA regulations also address acid deposition, climate change, mercury levels, nitrification, eutrophication, ozone, fine particles, regional haze, and impaired visibility. Research demonstrated that environmental control systems for the pollutants of concern were so interactive that strategies to address them collectively would be significantly more cost-effective.	• CO2 portion of program adapted to RGGI, which requires a 10% reduction in CO2 emissions from 2000 to 2004 baseline by 2017. • Global Warming Solutions Act (S2540) passed 2008, which requires 10 to 25% reduction of GHG levels from 1990 baseline by 2020, and 80% reduction from 1990 levels by 2050. • MA utilities plan to invest more than $1 billion over 3 years to triple the quantity of energy saved through energy efficiency (EE). MA will determine the air quality benefits from EE and include them in ozone and fine particulate plans due in 2013/2014.
New Hampshire (NH) (USA)	Clean Power Act passed in 2002 (HB 284). It required SO2 emissions to be reduced 87% below 1999 levels by 2006; NOX levels to be 70% below 1999 levels by 2006; CO2 levels to be reduced to 1990 levels by 2006; mercury emissions to be capped at level determined by technology study.	• CO2 portion adapted to RGGI program • Mercury study determined that emissions should be reduced by 80% from current baseline • Required NOX and SO2 emissions reductions have been met
North Carolina (NC) (USA)	Clean Smokestacks Act passed in 2002 North Carolina (SB 1078). NC power plants must reduce NOX emissions 77% by 2009, and SO2 emissions 73% by 2013, through three phases in 2007, 2009, and 2013. Required study of CO2 by 2005.	• Utilities must meet 2009 caps for SO2 and NOX. 2009 NOX emissions were 37,691 tons vs. 56,000-ton cap; 2009 SO2 emissions were 110,805 tons vs. 2013 cap of 130,000 tons. • Days that NC exceeded the ozone standard declined over 80% from 2006 • Fine particulate concentrations have declined about 15% since 2006 and now meet EPA air quality standards. • CO2 study required by the Act led to development of statewide Climate Change Action Plan covering all economic sectors.

Location	Description	Results to Date
European Commission (EC) (EU)	National Emissions Ceiling was established per Directive 2001/81/EC for SO2, NOX, VOC, and ammonia to address the cross-boundary pollution transport issues that were expected to persist after the achievement of the reduction targets of individual member states. These issues include the acidification of streams, lakes, and other water bodies, extensive eutrophication, and ground-level ozone. Extensive modeling found that using a multi-pollutant framework would permit the optimization of technology choices, both in terms of cost and energy efficiency, to meet various environmental objectives simultaneously. 2010 emissions caps for each member state are measured against 1990 baseline.	• Member state limits revised downward in 2005 • New targets established for 2020 • Directive 2008/1/EC, Integrated Pollution Prevention and Control sets additional standards for PM10, PM2.5, ozone, lead, and benzene, and requires comprehensive facility level review to minimize waste and energy consumption • Annual progress reports required from member states

Table 1. Examples of Multi-Pollutant Approaches

3.2 New Programs

In addition to programs that have been in effect for a number of years, there are numerous US state and local air quality agencies currently engaged in comprehensive planning processes. These planning exercises address multiple pollutants, including GHGs, and consider various sectors such as transportation, energy, and land-use to reduce costs and maximize benefits in air quality management. The planning techniques developed will serve as a template for US states to use to satisfy current and anticipated EPA requirements.[36]

3.2.1 New York

New York's Air Quality Management Plan (AQMP) is using a multi-pollutant approach, including GHGs, which emphasizes emissions reductions from the state's energy efficiency and renewable energy programs.[37] The results of the AQMP will be

[36] For more on the EPA's air quality planning pilots, see http://www.epa.gov/air/aqmp/pilot.html. St. Louis, Missouri is also part of the EPA pilot process, but that city's focus is air toxic emissions, whereas both New York and North Carolina's plans explicitly include GHG emissions.

[37] New York State Department of Environmental Conservation. A Conceptual Model for the Development of an Air Quality Management Plan for the State of New York. Final Draft, January 2009. Available at http://www.epa.gov/air/aqmp/pdfs/may2009/CMNewYork.pdf. A summary of current US planning efforts sponsored by the EPA is located at http://www.epa.gov/air/aqmp/pilot.html. The EPA also tracks New York state climate change activities at

used as part of an overall environmental planning process and as part of the EPA's efforts to build integrated planning capacity at the state level throughout the United States. New York's strong energy sector policies include several targets: acquiring 25% of its energy needs from renewable sources by 2013, decreasing energy consumption through end-use energy efficiency by 15% by 2015, and reducing GHG emissions by 30% by 2020 and 80% by 2050.[38] New York's plan will also include reductions in air toxics, such as mercury, formaldehyde, benzene, and polycyclic organic matter.

In a related effort, New York is also working with the regional multi-state air regulation coordination body, NESCAUM,[39] and the EPA to identify a set of policies to jointly reduce air pollutants (including toxics such as mercury) and GHGs. Results from a comprehensive modeling framework will provide regulators with information about the costs and benefits of proposed policies, their impacts and benefits on the energy sector, local economic effects (e.g., numbers of jobs created or lost), and reductions in ambient concentrations of fine particulates and ozone. The process will also identify any gaps in agency staff and expertise, which will then be corrected to assure sustained implementation of policies over time. The EPA's participation will inform their writing of guidance that other states and regions will use to prepare their air quality plans in time for the Clean Air Act deadlines of 2013-2014 for submission of strategies to reduce ozone and fine particulates.[40]

3.2.2 North Carolina

North Carolina is also working with the EPA to develop an integrated air quality management plan. Although the plan has not yet been completed, analysis is underway and its chief components have been identified. State air quality planners intend to initiate full implementation of the new planning process in 2013.[41]

The plan will focus on reducing emissions that contribute to the state's non-attainment status for ozone and fine particulates, and it will also address mercury emissions from coal-fired power plants, regional haze, and GHGs.

North Carolina is pursuing control measures that will maximize co-benefits. As a means to reducing fine particulate matter, North Carolina is considering control measures to reduce ammonia from animal operations in the agricultural sector. This approach would not only reduce $PM_{2.5}$ and improve regional haze, but would also reduce emissions of methane, a potent GHG. Another of the programs under consideration for reducing NO_X and $PM_{2.5}$ is an anti-idling rule, which would prevent heavy-duty truck operators from running their engines unnecessarily,

---

http://www.epa.gov/statelocalclimate/state/tracking/individual/ny.html

[38] New York State Energy Planning Board, 2009 State Energy Plan, Volume 1, December 2009. Available at http://www.nysenergyplan.com/final/New_York_State_Energy_Plan_VolumeI.pdf

[39] Founded in 1967 by an initiative of six state Governors, NESCAUM (Northeast States for Coordinated Air Use Management) coordinates air policy among eight Northeastern states (New York and New Jersey joined NESCAUM later).

[40] John Graham, NESCAUM. Applying the Northeast Regional Multi-Pollutant Policy Analysis Framework to New York. Presentation to NYSERDA EMEP Conference, October 14, 2009.

[41] Additional information about North Carolina's Air Quality Management Plan (AQMP) is available at http://www.epa.gov/air/aqmp/pilot.html

thereby reducing ozone precursors, fuel use, and greenhouse gas emissions. For reducing emissions of greenhouse gases from the transportation and utility sectors, the state's two largest contributors, North Carolina has identified energy efficiency and conservation as the most cost-effective policy option, which has the additional benefit of reducing SO_X and NO_X emissions.[42]

3.2.3 California

Although not part of EPA's multi-pollutant planning pilot effort to develop a template for states, the California Bay Area (San Francisco and environs) has been engaged in a similar process and, in September 2010, it adopted the first comprehensive multi-pollutant clean air plan of its kind in the US.[43] The Bay Area Air Quality Management District (BAAQMD) Board, the authorizing agency, is the regulatory body that develops and implements air quality plans for the San Francisco Bay Area of California, a seven-county jurisdiction with a population of approximately seven million.

The Plan applies to all pollutants, including criteria, toxic, and GHG emissions. It includes 55 control measures across stationary sources, mobile sources, transportation, land-use, and energy/climate sectors, many of which are designed to address root causes of emissions, not just end-of-pipe emissions. Such measures include, for example:

- GHG emissions incorporated into air quality permits;[44]
- Several transportation control measures, such as zero emissions vehicles, plug-in hybrid vehicles, improved transportation of commercial goods, public bus services, and integration of bicycling;
- Energy efficiency, renewable energy, and urban heat island mitigation; and,
- Indirect source review to set emissions standards for construction, operations, and vehicle traffic related to land-use and residential, commercial, and industrial property development.

Modeling conducted for BAAQMD by the University of California at Berkeley shows a strong correlation between the number of days the ambient temperature exceeds 99° Fahrenheit (37.2° Celsius) and the days in which ozone concentrations exceed the EPA standard of 75 ppb. Global warming is forecast to increase the number of such days, and thus impede the District's future progress in meeting the ozone standard. The Plan therefore focuses on measures that reduce both GHG and ozone precursor emissions as a way to ensure future compliance with both the EPA's and California's ambient air quality standard for ozone.

In addition to stated air quality objectives, the Plan also seeks to achieve climate and public health performance goals. These

---

[42] North Carolina's Air Quality Multi-Pollutant Process, prepared by the North Carolina Department of Environment and Natural Resources, March 2, 2010. Available at http://www.epa.gov/air/aqmp/pdfs/aug2010/northcarolinafinalaqmp.pdf

[43] The full Plan and Executive Summary are available at http://www.baaqmd.gov/Divisions/Planning-and-Research/Plans/Clean-Air-Plans.aspx

[44] Building on a recent decision, the Bay Area requires new power plants to demonstrate best available control technology for GHG. The Calpine Russell Energy Center (600-MW gas-fired plant) in Hayward, CA, will be the first such power plant in the United States with GHG limits in its air quality permits.

climate goals aim to reduce GHG emissions to 1990 levels by 2020 and 40% below 1990 levels by 2035. Public health goals aim to reduce $PM_{2.5}$ exposure by 10% by 2015, and reduce diesel PM exposure by 85% by 2020.

Because there is no standard model or template for agencies to develop a multi-pollutant plan, BAAQMD developed one, called the Multi-Pollutant Estimation Method tool, or MPEM. MPEM integrates concurrent goals of improving air quality and public health and reducing GHG emissions. MPEM's first step is to evaluate how a reduction in each pollutant of concern will affect ambient air quality and public health; then the model evaluates the combined impacts of each control measure. Uniquely, the Plan monetizes the benefits of control measures in terms of public health, climate mitigation, and compliance costs, to produce a value for each ton of pollution reduced. BAAQMD assigned a value of $28 per ton for CO_2 (estimated). A 1% reduction in pollutants is estimated to provide $158 million in health benefits from $PM_{2.5}$ (diesel, wood burning, secondary nitrates, and sulfates); $29 million in health benefits from reducing GHG, and $14 million in health benefits from reducing ozone.[45]

3.3 Recent Research and Analysis

There are excellent synergies from combined policies that reduce local air pollution, especially PM, and GHGs simultaneously. A recent study evaluated potential reductions from integrated policy action in both Western Europe and China.[46] It found that such an approach would result in more CO_2 reductions than either policy alone. Specifically the study found that a combined approach would result in additional CO_2 reductions of 15% in Western Europe and 20% in China. Other important findings of the study include:

- Policies focused solely on reducing local air pollution do little to reduce GHGs. End-of-pipe reductions and emissions control equipment reduce PM, NO_X, and SO_2 but have no effect on GHGs.

- In contrast, policies to reduce GHGs also effectively reduce local air pollution. Renewable energy and energy efficiency shift generation to lower-emitting resources and decrease demand for electricity produced by coal plants. These policies result in lower emissions of local air pollutants and GHGs.

- A dual policy focus on GHG and local air pollution results in greater reductions in local air pollution and GHGs than would have been achieved through a singular focus on either category of emissions.
- The environmental benefits of all measures analyzed more than outweighed their costs.

[45] Bay Area 2010 Clean Air Plan, figure 1-1, pp 1-14. http://www.baaqmd.gov/~/media/Files/Planning%20and%20Research/Plans/2010%20Clean%20Air%20Plan/CAP%20Volume%20I%20%20Appendices.ashx

[46] J. Bollen et al. Local Air Pollution and Global Climate Change: A Combined Cost-Benefit Analysis. Resource and Energy Economics, v. 31, 2009, pp. 161-181.

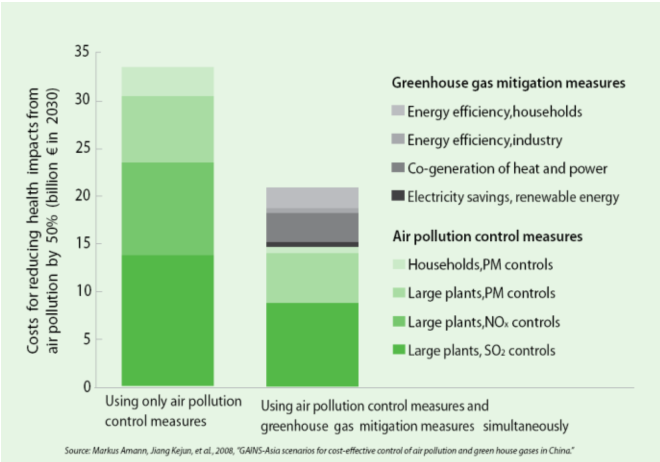

Figure 1. Cost Savings From Controlling Air Pollution and Greenhouse Gases Simultaneously, as Simulated by the GAINS-Asia Model[47]

Another study applying the GAINS-Asia model to GHG and air pollution policies in China found that the same air quality targets can be achieved at a much lower cost through measures that simultaneously reduce local air pollution and GHGs. Figure 1 describes these results.

The second bar shows a combined policy scenario in which GHG mitigation measures, such as energy efficiency, cogeneration, and renewable electricity generation, are used to reach air quality goals—at approximately 60% of the cost of using only air quality measures. Similarly for the EU, the modeling has shown that cost savings per ton of local air pollutant reduced can pay back as much as 40% of the cost of GHG mitigation.[48]

An earlier paper examined the local air pollution benefits to Europe from implementing the Kyoto Protocol.[49] Modeling of existing EU national emissions directives coupled with GHG reductions needed to meet Kyoto targets showed a strong correlation between reductions in CO_2 and SO_2, with high benefits also for PM. This linkage was related to decreased coal combustion, its sulfur content, and the resultant sulfate emissions that occur from combustion.

Several other studies from the United States, EU, and Asia[50] that evaluate the

---

[47] Graphic from UNDP China Human Development Report 2009/2010. China and a Sustainable Future: Towards a Low Carbon Economy & Society. Available at http://hdr.undp.org/en/reports/nationalreports/asiathepacific/china/nhdr_China_2010_en.pdf

[48] Markus Amann et al. Cost-Effective Emissions Reductions to Meet the Environmental Targets of the Thematic Strategy Under Different Greenhouse Gas Constraints. 2007 Available at http://www.iiasa.ac.at/rains/CAFE_files/NEC5-v1.pdf. Markus Amann et al. Potential and Costs for Greenhouse Gas Mitigation in Annex 1 Countries. Interim Report, November 2009. Available at http://www.iiasa.ac.at/Admin/PUB/Documents/IR-09-043.pdf

[49] D.P. van Vuuren et al. Exploring the Ancillary Benefits of the Kyoto Protocol for Air Pollution in Europe. Technical Report 93, European Environment Agency, 2004. Available at www.eea.europa.eu/publications/technical_report_2004_93

[50] This topic has been the subject of several conferences and workshops since 2008. Among them are:
(a) European Federation of Clean Air (EFCA) Strasbourg, France, November 6-7, 2008. Conference papers published in Pollution Atmospherique et Changement Climatique, Numero Special, Avril 2009 (in French and English). Conference summary available at http://efca.net/uploads/file/EFCA%20AP%20CC%20FINAL%20CONCLUSIONS.pdf
(b) Global Atmospheric Pollution Forum. Integrated Assessment of Co-benefits Between Air Pollution Control and GHG Mitigation. September 17-19,

benefits and costs of policies to reduce local air pollutants and GHGs provide consistent conclusions. A combined approach can effectively achieve the following:

- ***Capture synergies between industrial processes and the pollutants emitted by these processes.*** This synchronizes the benefits of reduced emissions on public health and the environment. Interactions and chemical changes of pollutants, such as the impact of SO_2 and NO_X on acid rain and fine particulates, and the impact of sulfate deposition in waterways on the methylation of mercury are also addressed. Black carbon is both climate-forcing and part of fine particulates. Higher temperatures caused by global warming can increase ozone concentrations, and ozone itself is a contributor to climate change. Methane concentrations affect ozone (and methane is the second most important GHG). Reductions in both ozone and methane will reduce global warming.[51]

- ***Amplify the overall value of the policy.*** Agencies typically rank air pollution control measures by their relative efficacy in reducing emissions and by their cost-effectiveness per ton of emissions reduced (expressed as $ per ton of pollutant removed).[52] This is a narrow focus that omits a broader range of societal considerations, factors such as public health (e.g., visits to hospitals or lost days of work), crop yields, effects on pollutant discharges of other media, effects on GHG and toxic emissions, and energy intensity. These factors may provide additional benefits (or costs) that improve (or impede) the policy's overall effectiveness. For instance, a GHG mitigation policy with an abatement cost of $50 per ton of CO_2 may not be considered cost-effective today, if GHG reductions are the only benefit being considered. But if the policy also reduces PM, NO_X, and SO_2 and has demonstrable public health benefits, then inclusion of these benefits in the policy analysis can significantly improve its cost-effectiveness.

- ***Capture lost opportunities****.* When integrated policies are not considered, opportunities are lost and benefits and cost-savings are not achieved. For example, it is often more expensive to retrofit technologies and insert control measures onto existing sources than to build efficiently from the start.

2008, Stockholm, Sweden. Conference summary available at http://www.sei-international.org/gapforum/conf/Integrated_Assessment_Paper.pdf
(c) Personal communication with John Murlis, former Director of Strategy and Chief Scientist, UK DEFRA, December 2009 and January 2010.

[51] P. Forster et al. Changes in Atmospheric Constituents and in Radioactive Forcing. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor, and H.L. Miller (eds.)], Cambridge University Press, Cambridge, UK (2007).

[52] An excerpt from Utah DAQ Guidance (a typical example) states: "Every facility, operation, or process that proposes any activity that would emit an air contaminant into the air, must by law consider the best control of all the emissions. You may achieve control by means of a) good process design, b) sound operating practices, c) best emission control devices available, or d) a combination of these means. Normally, DAQ expects the source to spend up to $5000 annualized cost per year for each ton of a regulated pollutant removed from its source. This amount may need to be higher, if your operation is in a non-attainment area." Utah DAQ Guidance. Available at http://www.airquality.utah.gov/Permits/FORMS/Form01b.pdf

- ***Encourage agencies to think about the point of regulation*.** The "point of regulation" is that stage of a process or supply chain at which the regulation applies. Explicitly addressing the point of regulation cures policymakers of their singular focus on end-of-pipe control options and uncovers a wide range of alternative—and more cost-effective—emissions-reducing strategies. Suddenly end-use energy efficiency improvements, clean energy resource choices, and structural changes, such as fuel switching or combined-heat and power, become effective policy tools. Alternative points of regulation can also reduce administrative and transaction costs and the complexity of program implementation.

The principles described in this section are distilled from today's global best practices. Ideally regulatory agencies should refer to and adhere to these principles as they consider policy design and implementation. In practice of course, reality intrudes and compromises have to be made. The next section discusses some of the challenges that regulators have faced and the solutions they found. These examples offer some lessons to agencies that are developing climate-friendly air quality plans today.

4. Institutional Practices: Lessons Learned

Why have agencies been slow to implement harmonized policies? In the United States, full adoption of multi-pollutant strategies has been slower than expected mostly because current laws are difficult to amend and because of the institutional barriers that arise when change is proposed. Major air pollution legislation (the Clean Air Act, or CAA) was adopted in the 1970s, and amendments to the law are very contentious. Under the CAA, states are accountable to the EPA to show that emissions targets are being met and that emissions are decreasing by a specific percentage annually. Formulae that fund state planning are linked to a state's particular pollution problems. These factors, and the failure of the law itself to recognize the interrelationships among pollutants, led to a federal-state administrative structure that has historically emphasized achieving single-pollutant air quality standards.

The problem is further exacerbated by the potential EPA-imposed penalties for the failure to meet emissions reduction requirements. They can be direct, as in the withholding from states of federal monies for other purposes (such as highway construction), or indirect, such as bans on permitting of new sources and more stringent regulations. As a result, and despite ample evidence of co-benefits from multi-pollutant approaches, state and local agencies continue to focus their resources on attainment and maintenance of ambient air quality standards. Many states that have completed ambitious and comprehensive plans to reduce GHG are stymied by existing funding and performance metrics that divert emphasis toward reduction of smog and fine particulates. Even though many of the recommended GHG reduction policies may also reduce smog, acid rain, and fine particulates and improve visibility and public health, these co-benefits are overlooked due to the agency emphasis on meeting narrowly defined pollutant-by-pollutant goals. And, even in agencies that are responsible for implementing both air pollutant and GHG programs, conflicts between the two can arise, and the old agency culture will determine which goal receives priority.[53]

Energy and environmental regulators at the federal and state level generally have not had a history of cooperation or coordination. Two US examples are exceptions to that history, and offer opportunities on which future policy design can be better coordinated and integrated.

One requirement of the 1990 US Clean Air Act Amendments was to form an organization whose charge was to address the transport of ozone precursor emissions in the eastern seaboard, to implement consistent policies that would ameliorate the effects of transported pollution, and to help those states to attain federal ambient air quality standards. The Ozone Transport Commission (OTC) is comprised of 12 states from Maine to Virginia and the District of Columbia. This region also encompasses three EPA districts. The EPA has actively

[53] R. Minjares et al. Challenges of Developing and Applying Integrated Strategies at Various Scales. Pollution Atmospherique, Avril 2009, Numero Special, pp. 19-22.

supported the OTC efforts to complete technical and scientific studies, to assess the effectiveness and costs of emissions controls, and to convene meetings between OTC states and those in adjacent, upwind regions (such as the Great Lakes). The OTC states agreed to consistent NO_X emissions standards for power plants, first implemented in 1995. The OTC program was the forerunner of the EPA's NO_X budget program, which expanded the coverage of consistent emissions standards from the 12 OTC states to more than 20 states east of the Mississippi River. And the EPA's NO_X budget program itself was expanded and strengthened in 2005 with the Clean Air Interstate Rule, and further expanded and strengthened in 2011 with the Clean Air Transport Rule. The groundbreaking work by the OTC states and the EPA led to agreement on the science, the technologies to control emissions, and the timeframe for which these technologies could be implemented without affecting electric system reliability.

A second example is the cooperation between state air quality agencies, the EPA, and federal land managers to develop plans whose goals are to reduce fine particle emissions and improve visibility. National Park and Forest Service managers worked with the EPA and states to identify the sources that produce pollution and affect visibility, and the Park Service constructed information kiosks in many national parks to show the public the type of air quality that leads to an optimal experience for the visitor (good days with visibility ranges of over 160 kilometers in western states, bad days with ranges of less than 10 kilometers in the west). States worked within regional planning organizations (such as the OTC) to develop consistent policies, agree on the emissions to be controlled, and set a timeframe for implementing the control measures.

Member states in the EU over the last decade have directed resources and policies toward measures that reduce GHGs.[54] The political leadership, structure of agencies, and agency funding has made this possible. Local air pollution programs, however, have not been coordinated with efforts to reduce GHGs. Different agencies are responsible for planning and implementing policies that reduce conventional air pollutants. As in the United States, responsibilities for reducing GHGs are often located in different agencies. In the United Kingdom for example, the Department of Environment, Food and Rural Affairs (DEFRA) is responsible for reducing local air pollution, and the Department of Energy and Climate Change (DECC), which was established as recently as 2008, is responsible for reducing GHGs. To help remedy this structural gap, the United Kingdom recently established an independent third-party Committee on Climate Change. This Committee has authority to oversee the United Kingdom's progress toward meeting its GHG obligations and to ensure policy coordination between agencies charged with implementing GHG and local air pollution measures.[55]

[54] For evidence of this, see: The EU Climate and Energy Package, March 2007 agreement, details at http://ec.europa.eu/environment/climat/climate_action.htm. See also, European Strategic Energy Technology (SET) Plan, proposed November 2007. Available at http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm

[55] The UK Committee on Climate Change is online at http://www.theccc.org.uk/

4.1 Institutional Best Practices

The scope of climate change policies spans across all economic sectors, from residential households to large industrial sources. Such economy-wide policies often require input and approval from several different government agencies and public stakeholders. To build broad support for climate-friendly air quality management, the planning, implementation, and assessment of policy measures must be coordinated within a structure that includes government leadership from a full range of affected sectors, the public, and academia.

Best practices for generating broad institutional support for air quality planning to successfully integrate GHG and local air pollution emissions include the following:

- Identifying the "champions" within the air regulatory agency and other key agencies to advocate for new policy measures and facilitate their implementation success.
- Institutionalizing clear and dedicated links between environmental and other key agencies, through an inter-agency climate policy planning committee and related procedures.
- Establishing robust and transparent communications between related agencies and affected enterprises to ensure that information is shared and used to enhance results.
- Understanding the complex interactions in atmospheric chemistry so as to better set priorities for actions, avoid unintended consequences, and make effective use of agency resources.
- Reaching agreement among parties as to the metrics by which to measure progress, and including tracking and assessment of policy impacts as an integral part of the air quality management planning process. Doing so helps ensure accountability, improves data collection from the outset, and helps inform agencies whether goals are being met and what revisions may be necessary.

Experience in designing policies, especially those that may be controversial, shows that support is needed from both the "bottom up" and from the "top down." Bottom-up policies, those suggested by advocates and the public, can be very effective, because they may already have broad support. Unless the advocates can address government's concerns about the costs or efficacy of proposed policies, however, it is often difficult to adopt them. Conversely, top-down policies can often be readily adopted, but unless the public and business are educated about the benefits of the policies, their goals may not be achieved. Some policies may lead to opposition that causes government to backtrack quickly to revise the policy.

Strong and consistent inter-agency communications can overcome a weak or inarticulate regulatory structure and can enable solutions that cut across economic sectors and lines of authority. One agency must ultimately be responsible for enforcement. Building codes, for example, can be developed by one agency and enforced by another as long as information is shared. Energy savings data can be evaluated, monitored, and verified by an energy agency, and the data shared with an environmental agency to determine the emissions benefits.

4.2 Lessons Learned

A thorough review of the design, implementation, and performance of programs reveals lessons for agencies to consider as they develop policy measures to simultaneously reduce GHGs and criterion pollutants today.

No single policy is perfect. Today, the EU Integrated Pollution Prevention and Control directive appears to be one of the best examples of climate-friendly air quality management. It requires comprehensive multi-pollutant and multimedia planning at the enterprise level to minimize and prevent waste and to minimize energy consumption. Yet the rules and structures for emissions reductions strategies are left up to the individual member states to develop, with varying success. As noted earlier, the United Kingdom assigns responsibilities for GHG and air quality planning to different agencies, thus creating the potential for policies to be at cross-purposes with each other.

Environmental agencies in the EU and the United States are mature, with more than 40 to 50 years of experience. The legislation and regulations that created those agencies were initially designed to address acute and singular environmental problems: black smoke from steel mills, open burning at garbage dumps, and so forth. As understanding of these problems evolved, agencies built on experience to find new ways to address them (e.g., reduce high ozone levels, reduce acid rain, and so on).

The most recent additions to environmental agencies' responsibilities are climate change mitigation and energy efficiency improvements. And as in the past, these agencies will turn to their decades of institutional experience for solutions, but ironically, this may prove more of a handicap than an asset. The same institutional memory and expertise that solved environmental problems on a single-pollutant and a single-medium basis may not be well suited to today's complex, interconnected challenges.

In many ways, China and other developing countries that are in the process of establishing environmental regulatory systems have a marked advantage over the veteran agencies in the United States and the EU. China has a clean slate. It is not bound by long-standing institutional history and practice. It can consider environmental and energy problems together through an economic lens to comprehensively and holistically reduce criterion and GHG emissions.

Lessons learned from the experience of EU and US environmental regulation can inform policymaking in China today. Key among them are the following:

Institute an open and multidisciplinary planning process that involves several executive branch agencies. The process matters. Participants from across all economic and emissions source category sectors can help to fully assess potential policies and the means by which their goals can be achieved, and then offer support for the policies during the critical initial implementation phase. Short-term goals are important to quickly achieve success and to ensure accountability to agency and officials. Medium- and long-term goals are also important. These allow for development of technologies that may not be currently cost-effective and for the benefits of measures, such as end-use energy efficiency, to accumulate over time.

Establish initial benchmarks based on the best information available at the time. The corollaries to this are "do not let the perfect get in the way of the good" and "do not get paralyzed by analysis." Agencies have launched programs to reduce local air pollutants and GHGs based on information that was later discovered to have been less than ideal.[56] Agencies assess the quality of the information available when decisions are being made about how much and how fast to reduce emissions. The efficacy of proposed standards can be adjusted to reflect this imprecision—that is, the agency may want to build in more time to achieve a goal or, in the alternative, discount the benefits of technologies or process changes that would be implemented.

Establish mechanisms for continuous evaluation and assessment. Several factors contribute to successful implementation of policy measures once they are initiated. Evaluation, monitoring, and verification of emissions reductions include adjustments of the terms and conditions in the affected sources permits and licenses, periodic source inspections and audits, enforcement actions with monetary penalties, and analysis of air quality monitoring data and emissions inventories. Updating analytical tools and models is also important. Air quality and energy models used by states in the 1980s were not able to appropriately evaluate decentralized and dispersed measures such as energy efficiency, small-scale renewable energy, and combined heat and power (CHP). Newer models and analytical tools not only are able to assess the effects of such resources and policies, but can also consider interactions between multiple pollutants and effects on other media, such as water quality and land.

Ensure adequate and sustained agency resources, with opportunities for training and professional development. Agencies need to have sufficient resources to implement and assess the effectiveness of programs adopted. Multiple sources of revenue are an advantage to help agencies adjust to periods of differential economic growth and types of industry located within their jurisdiction. Periodic training for staff and management is also important, to maintain staff expertise, to keep current on new technologies and process development, and to learn new analytical tools and methods.

Ensure that policies adopted can transcend their champions. Although it is difficult to replicate the energy of an individual in a regulatory structure, enduring success occurs when the implementation of policies is independent from their champions or chief advocates. The structure that enabled agreement on a policy to occur and then to initially succeed needs to be built into the agency culture at all levels and into its regulations. Absent this, the program may flounder when the champion leaves office or retires.

[56] The recently adopted RGGI is an example of this. States found differences between data recorded by CEMS and those reported by the same sources to the US Department of Energy. For this reason, the RGGI regulations included specific monitoring provisions to assure consistent emissions data. The RGGI architects also recommended changes to the information tracking systems of the regional electric transmission organizations to improve the tracking (recording) of electricity sales within and between the participating RGGI states. These data can help to serve as a cross-check with the actual emissions data reported via CEMS.

5. Policies for Climate-Friendly Air Quality Management

Numerous policies have been shown to effectively reduce GHG emissions and local air pollution and, although characterized by their particular political, economic, and social contexts, they offer lessons and principles that have implications for broader replication. This section will outline some of these policies along the following dimensions:

- Regulatory and Planning Approaches
- Energy Efficiency
- Power
- Building Codes and Standards
- Transportation
- Industry
- Appliances and Equipment Standards

5.1 Regulatory and Planning Approaches

5.1.1 Upstream vs. Downstream

"Upstream" and "downstream" are terms used to describe where in a production value chain a policy is applied. A downstream approach would apply to a point closer to the actual emissions source, be it a tailpipe or a smokestack. An end-of-pipe intervention, like a catalytic converter or scrubber, would be an example of a downstream control measure. An upstream approach, on the other hand, would apply to a point of regulation farther away from the actual emissions source. Because upstream approaches to air quality can create economic incentives for system-wide shifts in energy production and consumption, they tend to favor options that mitigate both GHG emissions and local air pollution.

Upstream approaches, like changes in industrial processes, improve the use of materials and the methods of operation, and thus result in lower emissions per unit of product manufactured. Economic benefits accrue to the manufacturer through reduced waste and avoided capital and operating expenses associated with installing and maintaining emissions controls. Substantial reductions in on-site energy consumption can also reduce the sizes of boilers and chillers needed and allow the facility to purchase smaller and less expensive replacements. This type of facility-wide emissions reduction assessment broadens the range of opportunities to achieve emissions reductions. Such policies thus should be carefully considered for climate-friendly air quality management.

Performance standards are a good illustration of upstream regulation. Emissions performance standards for power plants are mandatory in California, Massachusetts, Washington, and Oregon, and are currently under consideration in the EU. Another example of upstream regulation is minimum energy performance standards (MEPS), which the United States, Canada, and Australia have established for high-efficiency industrial motors. Market penetration of these motors now exceeds

70%, compared with 10 to 15% in the EU where voluntary standards were set.[57]

5.1.2 Integrated Planning and Permitting

Businesses with growing production and frequent process changes require the flexibility to implement these changes without agency pre-approval. Yet conventional permitting programs usually require that businesses submit an application prior to making any changes and certify that emissions will not increase.

The EPA, together with several states, developed a flexible and enforceable air permitting framework that has allowed participating industries to significantly increase production while decreasing their total facility emissions. A sample of the success stories from the pilot program includes:

- Intel's Aloha, Oregon, facility decreased VOC emissions from 190 to 56 tons per year while increasing production.
- 3M's St Paul, Minnesota, plant initially decreased its facility emissions from 10,000 to 4,300 tons per year, then lowered them further to less than 1,000 tons per year.
- DaimlerChrysler's Delaware plant reduced its emissions from 1,400 to less than 800 tons per year.[58]

Subsequently, in October 2010 the EPA promulgated regulations to provide clear and enforceable requirements for states and businesses seeking operational flexibility in their air permits.[59] The EPA permitting framework enables businesses to apply for and receive preapproval for a suite of process changes while maintaining enterprise emissions below an agreed-upon cap. Facilities taking advantage of the flexible US permits share many traits with businesses in China. Their businesses require frequent process changes to maintain growth and a competitive edge. For a company such as Intel, each day of productivity loss can amount to millions of dollars. Many US and Chinese businesses also market their green image, which is easier to verify when the enterprise operates under a permit that requires emissions per unit of production to decrease. By including all pollutants, including toxics, in the permit, businesses are also encouraged to think about life cycle emissions during the design of new products.

5.1.3 Integrated Resource Planning Tool

Recent studies have estimated the costs of air pollution from fossil fuel combustion, and have concluded that the effects of some older and larger power plants have external costs that exceed the retail electricity price where the generator is

[57] International Energy Agency. Proceedings of the Industrial Electric Motor Systems Efficiency Workshop: Industrial Motor Systems Energy Efficiency: Toward a Plan of Action. Presented May 15-16, 2006, Paris.

[58] Ross and Associates. Evaluation of Implementation Experiences with Innovative Air Permits. Summary Report prepared for US EPA, 2010. Available at http://www.epa.gov/ttn/caaa/t5/memoranda/iap_eier.pdf

[59] Federal Register, Volume 74, No. 192, Tuesday, October 6, 2009 pp. 51418-51440. Operating Permit Programs: Flexible Air Permitting Rule, 40 CFR Parts 70 and 71. Available at http://www.federalregister.gov/articles/2009/10/06/E9-23794/operating-permit-programs-flexible-air-permitting-rule

located.[60] These external costs have to be internalized in investment and planning decision-making processes to capture the external environmental and economic impacts from electricity generation into utility resource plans. There are different ways to do this. The simplest approach weighs resource choices according to their relative air pollution, giving additional points to resources like natural gas or CHP that favor them slightly over oil and coal in the resource selection process. More comprehensively, some state statutes now require utility resource plans to first procure all cost-effective demand-side measures and to fully include the external environmental and economic costs of supply-side resources. Specifically, in the states of Delaware and Utah, among others, planning is required to include such "externalities." Integrated Resource Planning (IRP) is a way to internalize these costs when evaluating for resource choices in the power sector.

Specifically, IRP, called Scientific Energy Planning in China, is a means by which all resource costs and benefits including unpriced externalities can be properly weighed in the decision-making process. Well done, it has the effect of driving investment toward cleaner, lower total cost resources, such as energy efficiency and renewables, which reduce both GHGs and local air pollution.

Electric sector planners and utilities complete periodic plans to forecast the quantity and types of energy and capacity resources that will be needed to provide reliable electricity service, given expected levels of demand over the planning horizon. These plans have historically focused on supply-side assets without evaluating the external consequences of these resource choices on the environment or the broader economy. IRP as practiced in the United States[61] and elsewhere has since evolved into a more complex economic analysis that integrates all resources and technologies available on the supply-side and the demand-side, to provide energy services at minimum total cost—including environmental and social costs—over the long term.

In simple terms, IRP makes it possible to compare options that have very different cost and operating characteristics. How does one accurately compare the costs and benefits of a coal-fired power plant with those of a wind farm? How does one compare a gas-fired plant with a hydroelectric plant, and how does one compare a clean coal-fired power plant with end-use energy efficiency? It is relatively easy to calculate the cost of power from each option, but a simple comparison of those costs (per kilowatt or kilowatt-hour) will reveal little about which options should be chosen. IRP is needed to determine how each option fits into the overall system—that is, how it affects reliability, business and financial risks, the environment, and other important considerations. In other words, IRP determines not only the costs of different resources, but also their *value*.

The planning horizon generally spans 10 to 20 years, with a specific action and investment plan developed for the near-term of 2 to 3 years. Total electricity

[60] The National Academy of Science. Hidden Costs of Energy. October 2009.

[61] IRP (sometimes referred to as Least-Cost Planning) is currently required in 23 US states.

demand is disaggregated by sector, end-use, and technology, with as much resolution as possible given available data. Based on these end-use demand breakdowns and electric demand forecasts, disaggregated projections of future levels of energy-service growth are made.[62] Technologies for improving the energy efficiency of end-uses and for influencing the timing and magnitudes of customer demands (i.e., their "load shapes") are identified. The technical performance and economics of these options are estimated, compared, and ranked according to cost-effectiveness. Based on these results, demand-side management (DSM) programs and other energy efficiency strategies are analyzed in terms of their total costs and rates of market penetration over time.

Then supply-side resources are analyzed. Production-cost analysis of the performance of existing and new electric supply-side resources is used to rank these options according to their marginal impacts on the total costs of the system (including environmental costs, such as local air pollution and GHG emissions) over the planning horizon. The results are compared to the marginal costs of demand-side options, including environmental costs—and benefits—to the extent possible. The two sets of options (supply-side and demand-side) are then compared and combined to produce the integrated least-cost electricity plan.[63]

IRP provides decision-makers with specific investment plans detailing how much of what types of resource should be added. Worldwide, IRP consistently shows that costs will be lower, the environment cleaner, security increased, and risk reduced through increased investment in energy efficiency and renewable energy. This has led to a wide range of policies such as Renewable Portfolio Standards and System Benefit Charges for energy efficiency and other clean resources. Furthermore, demand forecasts used in IRP can reflect the effects of complementary policies outside the strict jurisdiction of electric system regulators, for example,

[62] IRP consists of the following steps:

1. Identification of planning objectives. This is a key step because it is where national policies and priorities are built into the planning process. In particular, this is the step that incorporates energy efficiency, environment, energy security, and other national goals and that decides whether the objective function is to minimize energy costs (energy bills) or energy prices;
2. Collection of reliable data on electricity end-use demand patterns and technical alternatives for improving their energy-efficiency or load profiles (treating demand in terms of energy services, rather than merely kilowatt-hours to be produced);
3. Projection of future energy-service (end-use) demand scenarios;
4. Identification of the cost, operating, and environmental characteristics of all supply-side options (central station and distributed generation);
5. Identification of the costs and electric-load impacts of the demand-side alternatives;
6. Design of an optimal integrated supply- and demand-side plan that minimizes the economic costs and environmental impacts of electricity production and consumption over the long-term (the planning horizon);
7. Assessment of the risks of the plan and performance of sensitivity analyses to identify the lowest-cost means of minimizing those risks; and
8. Implementation of the least-cost strategy.

[63] The integrated electricity plan is subjected to further financial evaluation and sensitivity analysis before the final plan is completed. This step fine-tunes the results to account for specific issues and options inherent in the local or national setting.

energy efficiency standards, building sector energy efficiency standards, and environmental policy and regulations. In this way, the planning tool can indicate which energy efficiency programs and standards set at which levels will be most cost-effective to the overall system.

5.1.4 Reporting

Reporting criterion pollution and GHG emissions helps evaluate policy efficacy and provides accountability for the regulatory agency and the affected sources. Governments often direct funds to help implement emissions reduction policies, and reporting helps determine the success of the investments and whether the funds have been used as directed.

Three examples of different reporting methods illustrate the benefits of reporting and why reporting is an integral part of climate-friendly air quality policy:

1. The 1990 amendments to the US CAA required power plants to install, operate, and maintain CEMS for NO_X, SO_2, and CO_2. The EPA issued regulations that specified quality assurance and quality control procedures that include minimum data capture and precision requirements.[64] Affected power plants submit CEMS data to the EPA each quarter. The EPA in turn reviews and evaluates these data and publishes them to their web site, where they are publicly accessible. The CEMS data are used to:

- Ensure compliance and assess whether the emissions point is operating within its regulatory limits;
- Serve as a diagnostic tool for the power plant operators. Variations in emissions levels can be reviewed to assess boiler operation, to maintain the boiler in optimal condition to minimize fuel consumption per MWh of generator output;
- Verify data accuracy. Cross-referencing CEMS data with heat rates, fuel-use, and other plant data can help assess the accuracy of information as reported by emitters and determine whether pollution control equipment is being operated effectively;
- Certify emissions accounting in conjunction with regional emissions trading programs for NO_X and the national-level acid rain program for SO_2. CEMS data also guarantees credibility for the value of the allowance and consistency in currency throughout the United States;
- Produce emissions information records. CEMS data for CO_2 helped determine the emissions baseline for states that developed the RGGI. The EPA uses CEMS data graphically as a Google Earth data layer to show via time series the progress of emissions reductions since the acid rain and NO_X budget programs were implemented.[65]

2. The UK Committee on Climate Change (CCC) was established as an independent agency to advise the government and report to the UK Parliament annually on progress to meet its GHG reduction goals. Responsibility for implementation of the UK climate change plan is divided among several agencies,

[64] *See* US Code of Federal Regulations, Title 40, Part 75.

[65] *See* US EPA, Clean Air Markets, Interactive Mapping. Available at http://www.epa.gov/airmarkets/progress/interactivemapping.html

including the environmental agency, the DEFRA, and the DECC. A single and independent reporting agency offers several advantages:

- All data are assembled in one place;
- Implementation gaps are highlighted;
- The agency's independence provides a greater assurance that its assessment of programs will be unbiased.

The CCC's first report to Parliament in 2009 concluded that the current economic recession may be providing too optimistic an impression of how emissions reductions goals are being met, and that the UK government must increase its attention to and the pace of GHG reductions, especially in the energy sector.[66] It is doubtful that Parliament would have received such clear reporting had separate reports been prepared by each implementing agency.

3. In the United States at the state level, reporting of GHG emissions has been a key element of each of the climate change action plans that have been developed to date, and is required by many of the statutes that have authorized states to implement these plans.[67] When GHG reporting is linked to the reporting process for fine particulates and O_3, states can evaluate the efficacy of current and future policies to optimize reductions across all pollutants, and avoid implementing policies that trade reductions of one pollutant for increases in another. Timely and accurate reporting also helps agencies to evaluate the success of pilot-level actions and whether such efforts should be expanded. For example, data on cleaner diesel fuels and installation of particulate filters on construction equipment reflect that this equipment reduces fine particles and sulfur emissions, improves local air quality and public health, and reduces emissions of black carbon, which is a "climate forcer."[68] Data on emissions displaced by energy efficiency programs also help states to determine where to implement additional measures to further amplify the pollutant benefits, including those for GHG.

5.2 Energy Efficiency

Energy efficiency is as clean as the electricity it saves is dirty. Energy efficiency reduces the need for power generation and reduces all the pollution associated with that generation, both GHGs and local air pollution. It can help retire older, inefficient, and more expensive generation, and it reduces the sizes or capacities of emissions control equipment that would otherwise be required to meet air quality objectives. Energy efficiency will be a core component of any co-control strategy.

---

[66] UK Committee on Climate Change. Meeting Carbon Budgets - The Need for a Step Change. Progress Report to Parliament Committee on Climate Change, October 2009. Available at http://www.theccc.org.uk/reports/progress-reports

[67] Among the states with such requirements are each of the 10 states in the Regional Greenhouse Gas Initiative, in addition to California, Oregon, and Washington.

[68] Black carbon is considered to be a "short-lived climate forcer," which is to say that emissions of black carbon and their deposition on snow and ice hasten the speed with which melting of snow and ice occurs. The IPCC Fourth Assessment reflects that black carbon's climate forcing potential is from 1/30 to 1/3 that of CO_2. Research by NASA's James Hansen concludes that black carbon's climate forcing is much greater, at approximately one half that of CO_2. J.E. Hansen and M. Sato. Trends of Measures Climate Forcing Agents (Figure 1). Proc Natl Acad Sci USA 2001;98:14778-9.

Of significance, the evaluation, measurement, and verification required by energy efficiency programs to calculate progress toward energy savings targets is consistent with the protocols that will also calculate the quantity of emissions avoided by energy efficiency improvements. Quantities of emissions reductions achieved through energy efficiency thus can be readily verified and incorporated into air quality planning and emissions accounting.

Energy efficiency can be delivered through a variety of innovative regulatory and administrative means. One way is through an Efficiency Power Plant (EPP). An EPP represents a carefully selected bundle of energy efficiency programs designed to deliver a specified amount of capacity and energy savings over a specific time period. This bundling approach encourages cost comparison with conventional supply-side resources, allowing energy efficiency resources to be integrated into power sector planning and financing. Significant environmental benefits can be achieved through the energy efficiency power plant model (more details about EPP are provided subsequently).

In the United States and EU, air quality and energy officials have collaborated to develop energy policies whose benefits are now being considered and adopted to help meet environmental goals. Among the notable examples (described in the subsections following) are:

- Air regulators working with energy regulators and regional transmission organizations to ensure comparable treatment for demand- and supply-side resources in regional electricity capacity markets;
- Requirements for utilities to procure all cost-effective energy efficiency *before* new power plants are proposed;[69]
- Diverse funding for energy efficiency to sustain and build programs without solely relying on ratepayer or government funding;
- Revenue-based regulation of grid companies ("decoupling"), which breaks the linkage between sales and revenues, thus eliminating the financial harm that societally beneficial investments in energy efficiency impose on the companies.

5.2.1 Energy Efficiency as an Air Quality Control Measure

In the six New England states, the active involvement of air regulators helped the Independent System Operator for New England (ISO-NE) complete its recent 20-year scenario plan, as well as rules that comparably treat demand- and supply-side resources in the region's forward capacity market. ISO-NE has also worked with state air quality agencies to evaluate the emissions benefits from energy efficiency and renewable energy resources, and states there are now considering how to include these resources in their air quality plans. Approximately 700 MW of energy efficiency resources have cleared in New England's forward capacity market (out of a total capacity of approximately 28,000 MW), and the associated auction revenue that is being directed back to state energy efficiency programs is helping to invest in additional energy efficiency measures. The largest regional transmission organization in the United States, PJM, has recently adopted

[69] Generally the phrase "all cost-effective energy efficiency" refers to all available energy efficiency investments that are less expensive per kWh than the cost of operating a conventional coal plant.

rules that, although not as progressive as those of ISO-NE, also comparably treat demand and supply resources, and will lead to further investment in energy efficiency.

Connecticut's air quality agency is working with the EPA to qualify the energy efficiency resources that have cleared the forward capacity market as a control measure to help reduce fine particle and ozone pollution. Fifty MW per year of energy efficiency are estimated to provide approximately 1 to 2 tons per day reduction of NO_X emissions.[70] Although this quantity may appear small, state air regulators have previously considered and implemented control measures whose air quality benefits are measured in fractions of tons per day. And, compared to other measures that may be considered, energy efficiency is one of the most cost-effective means to reduce air pollution. The 50 MW per year of energy efficiency is also one of the top 10 measures in that state's climate change action plan to reduce GHG emissions 80% by 2050. Each MWh of energy efficiency displaces more than 0.5 tons of CO_2 that would otherwise be produced by a power plant.[71] Other states planning to include the benefits of their energy efficiency programs in their air quality and GHG plans include Massachusetts, New York, California, and Maryland.

5.2.2 Energy Efficiency Procurement Standards

One particularly beneficial tactic for reducing criterion and GHG emissions is to require all cost-effective energy efficiency measures to be first procured before a new power plant can be sited. Twenty-five US states have adopted energy efficiency standards that require utilities to procure a specified quantity of energy efficiency resources (in MW) or a specific percentage of energy (MWh) savings (e.g., 2% per year 15% below 2010 levels by 2015).[72] The EU's plan to reduce GHG emissions 20% by 2020 recognizes that, to achieve this reduction goal, energy consumption will have to be reduced by at least 20% below current levels. The EU estimates that reducing consumption by this amount will save EU member states the equivalent of €100 billion per year and reduce CO_2 emissions by 780 million tons per year.[73]

For the criterion pollutants, jurisdictions whose pollutant concentrations violate public health standards have fixed emissions budgets that cannot be exceeded. Each ton of fine particle pollution or ozone precursors emitted adds to the pollutant burden. Agencies must reduce emissions by more than one ton for each ton of new emissions to make any progress to meet air quality standards. One effect of the requirement to first invest in energy efficiency resources is a reduction in the generating output from power plants that are peaking or load following. Although not exclusively true, the emissions from peaking

[70] Personal communication, Richard Rodrigue, Connecticut Department of Environmental Protection, May 13, 2010.

[71] The quantity of emissions displaced is related to the emissions from power plants in each jurisdiction. Jurisdictions where coal is displaced will have higher emissions benefits per MWh of energy saved than in jurisdictions where natural gas is displaced.

[72] Pew Center on Global Climate Change, accessed July 2010. Available at www.pewclimate.org

[73] International Energy Agency, report on Task XXII- Energy Efficiency Portfolio Standards, initiated March 1, 2010 Available at http://www.ieadsm.org

or load-following plants in the United States are typically much higher per MWh than base-loaded plants, because such plants generally do not have modern pollution control equipment. They also tend to run below maximum output, given the variable nature of their load-following functions, and are thus less thermally efficient and more polluting per unit of output. Increased energy efficiency could be an effective means to retire older and less efficient power plants, especially in areas with poor air quality.[74] The emissions reductions could help these areas comply with public health standards and create headroom in the emissions budget to allow for construction of new and more efficient power plants.

5.2.3 Funding

Since the late 1990s, energy efficiency and renewable energy programs in the United States have benefitted from active government and ratepayer funding. This support has helped to build and sustain these programs, and significant energy and environmental benefits have been achieved. Air quality and GHG plans, however, reveal that to comply with more protective ambient air quality standards for ozone and fine particulates and to reduce GHG emissions at the 3% per year rate believed necessary to avoid global temperature increases of more than 2° Celsius, the rate at which energy efficiency and renewable energy programs are developed must be significantly increased. Tight government budgets and deficits and the reluctance of consumers to have their electricity rates increased substantially create opportunities to diversify how energy efficiency and renewable energy programs are funded. The EPP discussed previously is one excellent option. Other options being considered and implemented include:

- auctioning pollutant allowances and investing the revenue in energy efficiency and renewable energy programs;
- unbundling the environmental attributes of energy efficiency and renewable energy to help meet renewable energy standards or procurement goals, and investing the revenue from these programs in additional energy efficiency and renewable energy;
- creating a separate class as part of a renewable portfolio standard (or, more accurately, a clean energy standard) for energy efficiency.

Environmental literature emphasizes the benefits of auctioning GHG allowances, noting that utilities will price their electricity to include the additional CO_2 costs *even if they are given allowances for free*, and that failure to capture and invest this revenue will tend to increase utilities' profits without benefits to consumers.[75] This argument resonated with the architects of the RGGI in the United States, leading to the decision to auction nearly

[74] Even replacing like for like (e.g., coal for coal) would have emissions benefits per MWh. Older coal plants have thermal efficiencies of 30 to 33%, whereas new coal plants have thermal efficiencies of up to 45%. Each MWh produced by a new coal plant that replaced an old plant would result, in this example, in approximately 50% less pollution, including GHG.

[75] *See* UK and German auditor reports on EU ETS. It is because the CO_2 allowances have value in the secondary market that electricity prices will rise to reflect that value. Even if obligated entities receive the allowances for free, they will not give them away (i.e., surrender them) for free, if they have resale value. They will adjust their prices to capture that resale value or else sell the allowances.

100% of the CO_2 allowances and invest the auction revenue in energy efficiency and renewable energy.

During 2009, the RGGI CO_2 auctions returned $494 million to state energy efficiency and renewable energy programs. At a price of $35 per saved MWh, these funds were estimated to reduce CO_2, NO_X, and SO_2 emissions by a quantity equal to the output of one 1,000-MW coal-fired power plant.[76] Through March 2011, cumulative proceeds from the auction of CO_2 allowances for the ten-state region had amounted to more than $872 million.[77] States have invested a majority of these auction revenues in clean energy programs, providing an additional 10 to 30% to state energy efficiency funds.

The success of RGGI has helped the EU to progress further with its plans to auction allowances and to increase the percentage of allowances that member states can auction during each compliance period. RGGI states in turn are now considering the possibility of auctioning allowances of other pollutants, such as NO_X, and are considering stakeholder input as part of state plans to meet fine particulate and O_3 pollutant reduction requirements.

Another source of funding for state energy efficiency programs is revenue from the newly created forward capacity markets. The 50 MW of capacity resources from Connecticut (discussed previously) returned over $10 million to that state's energy efficiency fund in 2009, representing more than 10% of the annual program expenditures. The qualifying energy efficiency resources from Connecticut that clear the regional power pool's capacity market receive payments for as long as they yield demonstrable savings, in the same way that qualified supply-side resources receive payments for as long as they produce. And the revenue from the forward capacity market is expected to further increase as more energy efficiency resources are qualified.

5. 5.2.4 Performance-Based Incentives to Reward Superior Performance

Traditionally utility companies earn revenue based on their electricity sales to customers. The more electricity sold, the more revenue—and profits—the utility and its shareholders earn.[78] From the perspective of the utility, implementing energy efficiency interferes with this business model by reducing sales. Regulatory reforms can address this problem.

The first is to remove the grid company's financial disincentive to reduced sales. This can be achieved through revenue-based regulation, called *decoupling*, that breaks the link between the revenues that the utility is allowed to collect and its overall

[76] Personal communication, Derek Murrow, Environment Northeast, June 3, 2010. These amounts are estimates for comparative purposes.

[77] RGGI Inc. Investment of Proceeds from RGGI CO_2 Allowances. February 2011. Available at http://www.rggi.org/docs/Investment_of_RGGI_Allowance_Proceeds.pdf; and Economy-Wide Benefits of RGGI: Economic Growth through Energy Efficiency. March 2011. Available at http://www.env-ne.org/public/resources/pdf/ENE_RGGI_Macroeconomic_Benefits_110321.pdf

[78] This is because the utility's marginal cost of production is less than its marginal revenue, in almost all hours.

level of electricity sales.[79] Positive financial incentives, often referred to as performance-based incentives, reward utilities according to the amount of the energy savings achieved. Well designed performance-based mechanisms can improve administration of energy efficiency programs by rewarding increased program penetration and reduced program costs.

In the United States these incentives take several possible forms, including:

- **Shared Savings**, in which earnings are based on a specified percentage of "net" benefits—resource savings minus costs—or the avoided costs of energy efficiency.[80] Net benefits increase when the utility achieves cost-effective savings and project costs are reduced. The shared savings approach requires more detailed analysis than other approaches, including determining net benefits and accurately measuring and verifying savings.
- **Management Fees**, in which earnings are calculated as a specified percentage of energy efficiency program costs if the utility (or program administrator) achieves or exceeds approved program goals, including energy or capacity savings. The utility also may be required to achieve additional targets, such as program participation levels, installation rates for specified measures, and reductions in administrative costs.[81]
- **Standard Performance Contracting**, in which incentive payments are determined by the level of energy (kWhs) and capacity (kWs) savings from installed measures, under pre-established terms.[82]

Incentives need to be developed based on relevant local factors. What appears to be a good model in one area may be ineffective in another due to the electricity market, electricity rate structure, customer base and type of customer, and whether an energy efficiency program is already being implemented. Also, the type of incentive may need to change over time, to account for market changes and the effectiveness of energy efficiency programs.

Incentives should, for the most part, focus on electricity savings (kWhs, kWs) and be measurable, verifiable, and aligned with policy objectives.[83] Meeting and exceeding performance goals should be rewarded, and not meeting minimum savings goals should be penalized. California's mechanisms

[79] For a detailed description of decoupling, see Revenue Regulation and Decoupling: A Guide to Theory and Application, published by the Regulatory Assistance Project, June 2011.

[80] Typically the utility must achieve a minimum threshold of energy savings, capacity savings, or both to qualify for the incentive.

[81] The management fee approach does not necessarily focus spending on cost-effective programs and net benefits. Regulators can address this issue by tying incentive rates to well vetted, approved *budgets*, not utility expenditures, by adopting aggressive goals and clear performance metrics, and by exercising careful oversight.

[82] *See*, for example, Lainie Motamedi, The Regulatory Assistance Project. Texas Energy Efficiency Policy and Program Framework and Requirements. October 2009. Available at http://raponline.org/docs/rap_motamedi_researchbrief_2009_10_14.pdf

[83] As experience with energy efficiency and performance incentives has grown, policymakers and program administrators have begun to develop additional measures of achievement that are not directly related to kW and kWh savings. These measures go to program elements that relate to longer-term program efficacy—for example, wide geographic and customer distribution of efficiency services—to ensure that the programs are as fair and comprehensive as possible.

provide for a 9% incentive for utilities that achieve between 85 and 100% of energy savings goals and 12% for achieving greater than 100% of goals. No incentives are provided when 65 to 85% of savings goals are met, and penalties are applied for failure to meet 65% of savings goals.[84]

Creating incentives to reward utilities for meeting and exceeding energy savings goals also helps to guarantee that the anticipated emissions reductions will occur. These reductions are important in US states to meet progressive annual reductions required by the EPA to comply with ambient air quality standards, and in EU member states to meet national emissions ceilings and associated emissions reductions requirements. Inclusion of performance-based incentives is one of the factors that makes energy efficiency an enforceable emissions control measure.

5.3 Power Sector

A climate-friendly multi-pollutant strategy for the electric sector requires a re-evaluation of assumptions. The environmental regulator's challenge is not how to reduce emissions from a coal-fired power plant, but instead to find what is the best (i.e., cleanest) way to create a MW or MWh of electricity. Controlling criteria and toxic pollutants and GHG emissions simultaneously will lead to implementing end-of-pipe controls and measures that address the root causes of emissions.

When framing the policy objective in terms of emissions per unit of electrical output, resource decisions are driven toward the cleaner options, such as renewable energy, polygeneration, CHP, and increased gas-fired generation—and increased end-use energy efficiency.

Long-term regulatory signals help the electric industry plan for future environmental compliance costs and consequently shift resource choices away from fuels that cause or contribute to air pollution and global warming. And it will help environmental regulators recognize energy efficiency as a multi-pollutant control measure.

Below are several examples of power policies that can yield significant criteria and GHG pollutant reductions. To realize their full effectiveness, these policies should be designed with the active participation and coordination of environmental and energy agencies. There are two possible methodologies that air quality agencies in the United States use to determine the pollutant benefits of the policies included in this section:

- The criteria and GHG pollutant benefits can be included as part of the baseline that the air quality agency uses to forecast future economic growth and what measures will be needed to ensure that pollution is within anticipated limits to protect public health and the environment.
- The air quality agency can first determine the future emissions baseline without inclusion of the criterion and GHG benefits. Then the discreet benefits of each policy can be determined separately and subtracted from the baseline.

---

[84] Wayne Shirley and L. Schwartz, The Regulatory Assistance Project. Energy Efficiency Incentives for Utilities: A Review of Approaches So Far. Presented at the Idaho Office of Energy Resources Workshop, October 6, 2009.

The first method is how US national analyses are performed for the expected benefits of criterion and GHG control measures. Doing so tends to smooth out the roughness in the precision of estimating the effects of policies that have not yet been implemented or for which pilot level data is available. Also, because these policies can affect regional electricity grids, the energy models used are better able to account for the total system-wide energy and environmental impacts.

The second method is how local air quality agencies analyze the discrete benefits of a single policy. Local agencies are usually responsible for developing regulations and implementing them and need to know how the criterion and GHG benefits will occur and when. For example, the characteristics of local electricity generation and transmission can significantly influence what emissions are displaced by supply-side policy measures such as CHP and RPSs and by demand-side measures such as whole building retrofits and building codes. Implementation of policy measures that displace an uncontrolled fossil-fuel fired power plant will have greater local criterion and GHG benefits than policy measures that displace new natural gas plants or that effect distant power plants located in another province. These local vs. regional affects are important to understand, and they will influence the prioritization of policy measures to be implemented, and their location.

The following subsections highlight several environmental strategies for the power sector that may have particular relevance for China today:

- Energy Efficiency Power Plants;
- Environmental Dispatch;
- Pollution Fees with Revenue Recycling;
- Renewable Portfolio Standard;
- Feed-In-Tariffs for Renewable Energy;
- Emission Performance Standard; and
- Combined Heat and Power.

5.3.1 Efficiency Power Plants

The cleanest and lowest-cost kWh is the one saved rather than the one produced and consumed. An EPP is a bundle of energy efficiency investments designed to deliver an amount of capacity and energy savings over a specific time period. It is also a climate-friendly air quality management tool. A conventional coal plant burns at least 340 grams per kWh, emitting 4 grams of SO_2 per kWh, similar amounts of NO_X, and between 0.62 and 1.0 kilograms of CO_2.[85] By contrast, a 600-MW EPP satisfies the same energy service demand yet it burns no fuel and emits no pollution. Preliminary research estimates the average cost of an EPP is 15 fen/kWh.[86]

An EPP is a carefully selected set of DSM and energy efficiency programs that are designed to reduce demand and to meet specific load curve needs in the aggregate, whether base or peak load. In this way, EPPs allow energy efficiency to be integrated into power sector planning and financing as supply-side resources are.

One application of EPPs in China would be to require that proposals to construct new

[85] MIT, Future of Coal. Available at http://web.mit.edu/coal/The_Future_of_Coal.pdf

[86] The Regulatory Assistance Project, "The Efficiency Power Plant (EPP): An Energy Conservation Resource Management Project for the Asian Development Bank," July 2007.

coal-fired power plants include the construction of EPPs. Each MW of new coal capacity would be matched with some fraction of one MW of EPPs. This fraction would increase over time to become at least one half of one MW EPP for each MW of new coal-fired power plants. Such a policy builds on the successfully demonstrated policy of "small coal-fired plant closures," which has linked the approval process for new coal capacity to closing small, inefficient power plants.

The emissions output of coal-fired power plants in China varies significantly from region to region and from plant to plant because of differences in technology, thermal efficiency, coal quality, emissions controls (or lack thereof), size, and vintage. Smaller, older units are particularly inefficient and heavily polluting. By some estimates, plants up to 50 MW in size may burn between 100 and 260 grams more coal per unit of electrical output (kWh) than units 300 MW and larger.[87] By the end of July 2010, China had retired more than 70 GW of generation capacity, surpassing its target for the 2006-2010 period. According to the National Energy Administration, these closures mean annual emissions reductions of 1.1 million tons of SO_2 and 124 million tons of CO_2. In addition, the amount of coal consumed per kWh of generation output decreased from 370 to 340 grams per kWh.[88] Generators with a capacity of 100 MW or less now make up approximately 14% of China's coal-fired capacity, compared to 30%, or 115 GW, in early 2006.[89]

The small-plant closing policy is a short-term initiative. A climate-friendly air quality approach could transform the policy into one that will yield continuing and long-term thermal efficiency and emissions reduction benefits. Currently, implementation rules require that firms seeking to build new generating capacity first buy the operating rights from small plants, thus closing the small, dirty capacity and replacing it with capacity from new, efficient generators. As fewer and fewer small plants remain, the same policy could require that new supply-side resources build or fund others to build EPPs under the supervision of responsible central or provincial agencies. The policy could be designed to match or exceed the net environmental benefits of the current small plant policy.

Another potential vehicle for implementing EPPs in China could be through the Environmental Impact Assessment (EIA) process. Currently some jurisdictions in China are requiring new projects to compensate for their expected SO_2 emissions (as identified under the Total Emissions Control program) through the purchase of SO_2 offsets from other plants that are either closing down or upgrading pollution controls. Similar to these emissions offset requirements, the EIA

[87] National Bureau of Statistics of China, National Development and Reform Commission, Asian Development Bank, as presented by the University of Cambridge. Energy Status and Emissions Scenario in China. 11 December 2008, slide 7. Available at http://www.eprg.group.cam.ac.uk/wp-content/uploads/2009/01/niu-pdf.pdf

[88] Xinhua News Agency, 30 July 2009. Available at http://news.xinhuanet.com/english/2009-07/30/content_11799786.htm

[89] BusinessGreen.com, 31 July 2009. Available at http://www.businessgreen.com/business-green/news/2247059/china-closing-small-coal-fired

could obligate new projects to offset a portion of expected energy use through investment in EPPs. This policy could help a jurisdiction control growth in electricity demand and stay within the guiding range of total energy consumption.

5.3.2 Environmental Dispatch

The existing dispatch system in China allocates roughly the same number of hours of operation to all thermal power plants. This is very different from typical dispatch systems around the world, which dispatch power plants according to their marginal operating costs. The 2007 Energy Conservation Law, later detailed in an National Development and Reform Commission (NDRC) circular issued in August 2007, put forth a new approach to dispatch, one in which environmental considerations have priority. This "environmental dispatch" rule requires that the dispatch, or loading order, of power plants be determined on the basis of units' sulfur dioxide emissions and thermal efficiencies.[90]

Although the new dispatch rule has been only partially implemented through pilot projects, and obstacles to its wider adoption remain, the benefits are estimated to be substantial. A recent study by the World Bank estimates that full implementation could result in a 3% reduction in coal consumption and overall gains in efficiency of 10 grams of coal equivalent per kWh.[91] Evaluating and ultimately revising the 2007 environmental dispatch rule could maximize its coal savings and air quality co-benefits. This could include expanding the rule to give high-priority dispatch to other low-carbon options, including capture-ready integrated gasification combined cycle (IGCC) and polygeneration meeting specified carbon emissions standards.

5.3.3 Environmental Fees and Recycling Revenue

China's pollution levy system covers an extensive range of water and air pollutants. It was structurally modified in 2003 from a levy that applied to discharges in excess of allowed levels to one that applies to all pollution emissions. Rates are determined by the MEP and are enforced by the local Environmental Protection Bureaus (EPBs). Regional EPBs are also charged with administering the funds generated from the tax revenue, which are designated for environmental projects, such as pollution control technology. In 2004, the levy for SO_2

[90] The order calls for the operation of non-emitting resources first, then low-emissions resources, and finally the higher emitting units. Specifically, power plants will be scheduled to meet hourly demand according to this dispatch sequence:

1. Non-dispatchable renewable energy generating units, such as wind, solar, ocean, and run-of-river (i.e., non-storage) hydropower facilities;
2. Dispatchable renewable energy facilities, such as hydropower with storage, biomass, and geothermal units;
3. Nuclear facilities;
4. Combined heat and power units that meet specified thermal efficiency criteria and whose operations are determined by thermal energy demand;
5. Natural gas, coal-bed gas, and coal-gasification generating units;
6. Coal-fired generating units, including combined heat and power generating units not meeting minimum thermal efficiency requirements; within this category, power plants with the same heat rates (thermal efficiency) will be ranked according to their emissions of air pollutants (per unit of electrical output); and finally,
7. Oil-fired generating units.

[91] The World Bank. Improving the Efficiency of Power Generation Dispatch in China. August 2010.

emissions from electric power plants was raised from $24 per ton (200 Renminbi (RMB) per metric ton) to $76 per ton (630 RMB per metric ton). The levy was increased again in 2007 to $152 per ton (1260 RMB per metric ton) and is now slightly higher than the average cost to control emissions but well below the damage costs. The system still has weaknesses, including (*1*) failures of local enforcement and (*2*) the failure to apply it to CO_2, NO_X, and methane emissions, chief among the GHGs.

A climate-friendly air quality policy approach would be to revise and evaluate the recycling of environmental taxes and levies to directly invest in programs and technologies that further reduce emissions. There are multiple modifications to the pollution levy system that could bring near-term results:

- Expand the levy system to the full range of power sector air emissions, including $PM_{2.5}$, O_3, CO_2, and other GHGs.
- Set fees to increase over time according to a publicly posted schedule.
- Direct a majority of revenue from the pollution levy to investment in end-use energy efficiency and other pollution prevention options.
- Improve implementation and enforcement of the levy by better integration with power sector regulation, by:
    - Requiring CEMS capable of monitoring heat rate (carbon emissions) as well as other key pollutants;
    - Basing dispatch decisions directly on CEMS data;
    - Modifying regulation to clarify that power plants emitting more than specified levels of air pollutants will be not dispatched; and
    - Clarifying that non-payment of fees will also disqualify a power plant for dispatch.

5.3.4 Differential Electricity Pricing for Industries

Since 2004, China has relied on an electricity pricing innovation that applies discriminatory electricity prices to less efficient industrial end-users.[92] Nationwide, it targets eight energy-intensive industries, and ranks enterprises according to four classes of energy efficiency. The least efficient class receives the highest electricity price; the most efficient receive the most favorable price. The revenue collected through the price difference is re-invested into energy efficiency programs.

The policy has had the effect of encouraging enterprises to upgrade inefficient production processes and of forcing the closure of the least efficient facilities, with substantial energy savings and emissions reduction benefits. This scheme could be expanded in several ways, among them the following, for example: (*1*) imposing more punitive prices on the least efficient facilities; (*2*) applying to pollution-intensive industries, as well as energy-intensive industries; and (*3*) taking into account pollution emissions in the system of classification.

5.3.5 Renewable Portfolio Standard

Local air pollution and GHG emissions from the electric sector can be reduced through two ways: by reducing demand and by

[92] 差别电价政策 (发改电（2004） 159号). (Differential pricing policy (Power Development and Reform Commission (2004) 159).

generating cleaner supply. One policy used broadly around the world to increase the share of cleaner resources in generation mixes is the Renewable Portfolio Standard, or RPS. China's renewable mandate share requirement on the utilities is a one form of such a policy.

In the United States, RPSs have been adopted by 29 US states and the District of Columbia.[93] RPSs in three states, Connecticut, Nevada, and Pennsylvania, also mandate that part of the standard be met through CHP and DSM. Connecticut's RPS establishes a separate class of resources for CHP and DSM; it requires that 4% of the 14% 2010 requirements be provided by CHP and DSM.[94] Nevada's RPS applies to investor-owned utilities and required them to initially provide 6% of 2005-2006 annual electricity sales through renewable energy. This quantity increases to 20% by 2015. Of the total RPS, energy savings from energy efficiency programs can provide up to 25%, or 1.5% in 2005-2006, increasing to 5% in 2020.[95]

Pennsylvania's alternate energy portfolio standard requires that 18% of that state's electricity sales be provided by renewable resources by 2020. The portfolio of DSM measures and CHP are included in the tier II category, which is required to provide 10% of the system's overall energy, or nearly two thirds of the 18% RPS by 2020.[96]

5.3.6 Feed-In-Tariffs for Renewable Electricity

A feed-in-tariff is a renewable energy policy that offers guaranteed payments to renewable energy developers for the electricity that is produced. Feed-in-tariffs have been responsible for rapid growth and penetration of solar photovoltaic (PV) technologies in several European countries, including Germany, Italy, and Spain.

Germany reached its 2010 renewables target of 12.5% by the end of 2007.[97, 98] Encouraged by this success, the German government promptly increased its 2020 target from 20% to between 25 and 30%.[99] The 2007 progress report by the German government quantified renewable energy benefits of reduced electricity prices, avoided fuel imports, avoided emissions,

[93] As of March 2010, six additional states have voluntary goals. See www.dsireusa.org.

[94] Connecticut General Assembly Public Act 05-1, 2005. Available at http://www.cga.ct.gov/2005/ACT/Pa/pdf/2005PA-00001-R00HB-07501SS1-PA.pdf. Legislation was since amended in 2007 by Public Act 07-242. Connecticut's RPS increases each year, and by 2020, requires that 27% of the state's annual electricity sales be provided by renewable resources.

[95] Nevada Assembly Bill 3, 2005. Available at http://www.leg.state.nv.us/22ndSpecial/bills/AB/AB3_EN.pdf

[96] Pennsylvania's RPS also includes waste coal and integrated combined coal gasification technology. General Assembly of Pennsylvania, Senate Bill 1030, November 17, 2004. Available at http://www2.legis.state.pa.us/WU01/LI/BI/BT/2003/0/SB1030P1973.pdf

[97] Gerhard Stryi-Hipp. Experience with the German Performance-Based Incentive Program. German Solar Industry Association (BSi). For Solarpower 2004, San Francisco CA. 19 October 2004. Available at http://www.wind-works.org/FeedLaws/Germany/Stryi-Hipp_Experience_with_EEG.pdf

[98] US Solar Industry Year in Review 2007. SEIA. Available at http://www.seia.org/Year_in_Review_2007.pdf

[99] German Cabinet Adopts Climate and Energy Package. International Energy Agency (IEA). 24 September 2007. Available at http://www.iea.org/textbase/papers/roundtable_slt/slt_germany.pdf

and new jobs at €9 billion (about $13 billion) annually.[100] As of 2007, Germany had created 250,000 direct jobs across the renewable energy sector as a result of the significant growth of renewables.[101]

Germany has approximately 10 GW installed capacity as of December 31, 2009, with approximately 3.8 GW installed during 2009.[102] Feed-in-tariffs have also increased PV resources in Spain and Italy. Spain had 3.2 GW of installed PV capacity as of December 31, 2008, and Italy added 730 MW of PV during 2009.

In the United States, the state of Washington passed SB-6170 in May 2009 to encourage development of distributed PV. Installations of 25 kW or less are eligible for production payments of $0.30 per kWh, with payment terms that extend to 2020. Oregon's HB-3039 (June 2010) establishes a 15-year guaranteed incentive to customers who install small and medium-scale PV systems. Small-scale (less than 10 kW) systems are eligible for incentives of $0.55 to $0.65 per kWh (depending on their location); medium-scale incentives (10-100 kW) are set at $0.55 per kWh.[103]

EU member states and US states that have implemented feed-in-tariffs emphasize the GHG reduction benefits that can be gained from developing renewable resources. Although adoption of feed-in-tariffs has resulted in significant increases in the quantity of global PV generation, however, several caveats should be noted regarding their implementation:

- Generous incentive payments in the EU increased demand rapidly, which outpaced the ability of manufacturers to satisfy the demand. Global silicone prices spiked, which impeded PV development in other countries, notably the United States.
- Inverter production has lagged that of PV, leading to shortages in several countries.
- Feed-in-tariffs are not well coordinated with environmental policy. Although several countries note the GHG benefits, complementary benefits to criteria pollutants have not been reported.
- Linkages between feed-in-tariffs and other energy policy measures are not clear. For example, a well coordinated energy policy would first focus on improved energy efficiency of whole buildings prior to installation of PV panels.

5.3.7 Emissions Performance Standard

Another strong policy option for reducing air pollution and GHGs from the electric sector is emissions performance standards (EPS) for power plants, currently in effect in California, Massachusetts, Washington, and

[100] Gabriel: An outstanding success story. Federal Environment Minister presents progress report on Renewable Energy Sources Act. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. 05.07.2007. Available at http://www.bmu.de/english/current_press_releases/pm/39678.php

[101] Development of Renewable Energies in Germany in 2007. 12 March 2008. Available at http://www.bmu.de/files/pdfs/allgemein/application/pdf/ee_hintergrund2007_en.pdf

[102] European Photovoltaic Industry Association. A Bright Future Shines on the Solar Photovoltaic Electricity Market. April 12, 2010 (media release in conjunction with 5th Workshop on Market Potential and Production Capacity, March 19, 2010, Rome, Italy).

[103] Fact Sheet on Oregon Feed-In-Tariff, HB-3039, June 2, 2010.

Oregon, and currently under consideration in the EU, United Kingdom, and Canada.[104] The emissions performance standard is a minimum performance standard for electric generating facilities, set in terms of a maximum amount of GHGs per unit of output. In California, the EPS is expressed in pounds of CO_2 equivalent (CO_2e) per MWh (in the EU, it is expressed in grams of CO_2e per kWh).

The numerical standards established by California take the emissions of a combined-cycle gas turbine as the threshold for performance, or 1,100 lb per MWh. It requires that all new long-term commitments involving base-load generation facilities must meet the standard of 1,100 lb CO_2 per MWh. This affects all long-term contracts pertaining to new plant construction and new investments to existing facilities, for new and renewed contracts both in and out of state. California regulators also defined several renewable resources, including solar thermal, wind, geothermal, and certain biomass to energy facilities as EPS compliant.[105]

By applying regulatory leverage at the point of long-term contracts, those 5 years or longer, the California Public Utilities Commission expects it will capture approximately 78% of all new utility transactions. By way of comparison, conventional coal-fired power plants generally have a CO_2 emissions rate ranging from 2,000 to 2,500 lb/MWh. An integrated gasification combined cycle plant can have an emissions rate ranging from 1,600 to 2,000 lb/MWh. The EPS therefore virtually freezes construction of new coal generation, because no coal-fired plant can meet the standard without carbon capture and sequestration (CCS) technology to dramatically reduce emissions. The California ruling, however, allows the standard to be met over the lifecycle of the plant. This forces new proposals to include viable plans now for retrofitting facilities with CCS later once the technology comes online, such that the facility's average emissions rate meets the standard over the course of its lifetime. The requirement for advance planning by industries is a regulatory approach that can have benefits in other areas as well.

Washington's EPS was also passed in 2007 and establishes a 1,100 lb CO_2 per MWh emissions standard. The EPS applies to long-term supply contracts with a capacity factor greater than 60%. Like California's EPS, Washington's also defines certain classes of renewables as de facto compliant with the emissions standard.[106] Oregon has also passed an EPS, but implementation regulations have yet to be developed by the state's public utilities commission.

[104] An emissions performance standard has been under consideration in the EU since their Emissions Trading Scheme began in 2005. Recent concerns that an EPS would depress the value of EU ETS allowances have delayed further consideration of an EPS. EPS continue to be advocated in the EU and the United Kingdom as a means to promote clean energy development. Canada also continues to discuss adoption of EPS.

[105] California Public Utilities Commission Decision 07-01-139, issued January 25, 2007. Available at http://www.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/64072.htm

[106] Washington Senate Bill 6001, effective July 22, 2007.

5.3.8 Combined Heat and Power

CHP refers to systems that produce both electricity and thermal energy, sequentially in a single integrated installation. CHP, also called co-generation, represents a range of technologies that offer large commercial and industrial installations the ability to generate their own electricity and to recover the heat from the fuel combustion process on-site, for use in other industrial processes or for local heating needs. The thermal efficiency of CHP is typically greater than 60% and can exceed 90% (compared with a conventional power plant with 35% thermal efficiency or supercritical coal-fired power plants with thermal efficiencies of 45%).

CHP installations are one of the most cost-effective policies to reduce GHG and criteria pollutant emissions. Analysis of GHG abatement options in the United States by the consulting firm McKinsey & Co. indicates that CHP "costs" –$30 to –$60 per ton CO_2e, illustrating CHP's significant economic benefits.[107] CHP is also identified as a top ten measure in US states' climate change action plans to meet long-term GHG reduction goals.[108] CHP also qualifies as an eligible technology to meet state RPS requirements.[109] To support the increased deployment of CHP in the United States, the EPA has prepared a calculator to help states and project developers estimate the quantity of SO_2, NO_X, and CO_2 emissions that can be displaced by CHP.[110] The calculator's spreadsheet is populated with default data reflecting the average emissions from several existing generation sources.

CHP is not new to China. As part of the national efforts to reduce energy intensity, the Chinese government has been a strong supporter of CHP since the 1980s and, as of 2006, the country ranked number two in the world for installed CHP capacity.[111] As of 2008, 13% of electricity generated in China came from CHP facilities. Despite this undertaking, however, there is considerably more opportunity for CHP in China. The International Energy Agency estimates that a favorable policy environment could enable CHP to meet as much as 27% of China's electricity generation by 2030.[112]

Whereas most applications in China provide thermal heat for industrial purposes, CHP for district heating networks is broadly used in the residential sector as well. Nearly half of all Chinese cities had some district heating infrastructure in place as of 2005. Yet many of these existing facilities are old and coal-fired, with limited pollution controls, low thermal efficiency rates of 60 to 65%, and high heat loss in the pipeline networks. [113] The MEP has recently identified residential heating reform as a key step toward improving air quality in

---

[107] McKinsey & Company. Unlocking Energy Efficiency in the U.S. Economy. July 2009.

[108] For example, Maryland, Connecticut, Colorado, New York. *See* www.climatestrategies.us

[109] CHP qualifies for RPS requirements in Arizona, Connecticut, Hawaii, Massachusetts, North Carolina, Nevada, Ohio, Pennsylvania, and Washington. Available at http://www.epa.gov/chp/state-policy/renewable_fs.html

[110] Combined Heat and Power Emissions Calculator. Available at http://www.epa.gov/chp/basic/calculator.html

[111] International Energy Agency, The International CHP/DHC Collaborative, County Scorecards, China. Available at http://www.iea.org/G8/CHP/profiles/China.pdf

[112] International Energy Agency. Cogeneration and District Energy. April 2009. Available at http://www.iea.org/files/CHPbrochure09.pdf

[113] IEA, CHP/DHC, China Country Scorecard.

China's cities. The May 2010 State Council circular on Joint Prevention and Control of Air Pollution to Promote Regional Air Quality (国办发 [2010]33号) limits the construction of new thermal electric generation facilities to CHP in urban areas, and calls for the development and expansion of urban residential and commercial district heating to replace small-scale coal burning.

With traditional heating zones in China covering some 70% of the country's landmass and 40% of the population, there are significant opportunities for expansion and upgrades, especially in the northern cold climate regions. These northern regions are also those in which the renewable energy resources are concentrated, which creates an additional opportunity for GHG and local air pollution emissions reductions. These northern grids currently experience high rates of wind curtailment, because much of the thermal generation fleet is CHP with district heating, which takes priority in dispatch due to residential heating needs. Policy-makers and system operators are engaged in resolving this problem; the involvement of environmental regulators in this effort will improve the odds that the solution will best meet the several policy objectives.

Thermal storage in the form of large hot water tanks can be used for short-term energy storage of excess renewable power within CHP systems. The hot water tanks provide flexibility to integrate and balance intermittent renewables, through up and down regulation to the grid, while also producing hot water for residential heating purposes. Denmark is a leader in this technology, where more than 60% of homes are heated through district heating and with 80% of district heating from CHP plants. Insulated hot water tanks can store the energy for many hours, helping Denmark achieve a 20% share of wind power in electricity generation in 2009. Similar applications in China's north can help reduce local air pollution and GHGs through improved energy efficiency and integration of renewable resources.

5.4 Building Codes and Standards

In the United States, buildings consumed $406 billion worth of energy in 2009, or 38% of total US energy spending.[114] The average American household spends $2,150 each year on home energy bills.[115] Building codes, however, can cut these costs dramatically. Meeting energy standards in building codes typically cuts home energy costs by 15% or more, saving the average household more than $300 each year.[116] A recent study found that investing only a fraction of 1% of the value of construction projects in building code compliance and enforcement initiatives would provide sufficient resources to achieve 90% compliance with energy codes. Indeed, a recent study found that each dollar spent on code compliance achieves a six-fold payoff in energy savings; full funding will eventually save American consumers $10.2 billion and 30 million tons of CO_2 annually.[117]

[114] Institute for Market Transformation, Policy Maker Fact Sheet. Building Energy Code Compliance, October 2010. Available at http://www.imt.org/codecompliance.html

[115] *Id.*

[116] *Id.*

[117] *Id.*

With China's urbanization rate approaching 50%, energy use and GHG emissions will begin to shift away from industrial sources and will be increasingly dominated by the building sector. Estimates from the World Bank suggest that roughly half of the world's construction between now and 2015 will take place in China.[118] In the country's dense urban areas, this shift has already begun, and the challenges faced are similar to those in New York City, for example, where the building sector accounts for as much as 75% of CO_2 emissions. Improving the energy performance of old buildings and ensuring the high performance of new buildings will have enormous impacts on GHG emissions and air pollution long into the future. China has set aggressive targets in the 12th Five-Year plan that aim at reducing the energy and carbon intensities of buildings nationwide. More stringent building codes have been introduced to address new construction. Market-based transformation initiatives such as Leadership in Energy Efficiency Design (LEED) rating systems have taken hold in China as well. Many buildings are exploring incremental steps in improving the performance of building envelopes, HVAC systems with the goal of reducing energy usage.[119] The following examples may be useful in furthering China's efforts in this area.

5.4.1 Whole Building Retrofits

Optimizing energy savings through projects that focus on the entire building envelope lead to significant environmental and economic benefits. Advantages of whole building retrofits include:

- Effective customer contact: all facets of the building or premise are discussed with the customer at the same time.
- Energy savings throughout the building can lead to additional energy, economic, and environmental benefits through replacement of boilers and HVAC systems, and sizing these systems to better match the new, lower building energy demand. This approach in turn leads to longer equipment life, because the boilers, motors, and so on are operating within normal ranges and are not oversized.
- Eliminates "cream skimming" in which only the most cost-effective measures that produce quick benefits, such as new lighting, are completed, but more significant and longer-term energy savings are ignored.

Whole building retrofits can reduce energy consumption by 25% or greater. An example of what can be achieved and its potential scale is the planned retrofit of the Empire State Building in New York City. When completed, the new energy saving measures are expected to reduce energy consumption by 38%, reduce CO_2 emissions by 105,000 tons over 15 years, and save more than \$4.4 million annually in energy costs.[120] Among the measures being completed are replacement of all 6,514

[118] Li, J. Climate Resilient Urban Infrastructure in China—Insights into the Building Sector. P. 4. 2009. Available at http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1256566800920/6505269-1268260567624/Li.pdf

[119] China Greentech Initiative. China's 12th Five-Year Plan: Implications for Greentech. March 2011. Available at http://china-greentech.com/sites/default/files/12thFYPImpactonGreentechbyCGTI.pdf

[120] RMI Retrofits America's Favorite Skyscraper. Available at http://www.rmi.org/rmi/RMI+Retrofits+America%27s+Favorite+Skyscraper

windows in the building and addition of a low emissivity film and gas mixture between the glass panes. Building energy demand will decrease by 3.5 MW and cooling load will be reduced by 33%. The project will be completed by December 2013.

5.4.2 Mandatory Building Codes

One city in the United States, Austin, Texas, adopted a housing ordinance in October 2006 that restricts the size of new and remodeled single-family homes.[121] Homes are limited to the greater of 2,300 square feet or a 0.4 floor-to-total lot area ratio that applies to all residential units located on one lot. Austin also requires homes in designated districts to meet green building standards according to a rating system developed by Austin Energy, the municipality's electricity provider. Homes are rated from one to five stars (five being best) depending on the type and performance of energy savings features (which also include water efficiency).

China has mandatory building energy efficiency codes (BEECs), which were first implemented in 1995.[122] Each BEEC is, in theory, expected to achieve 50% energy savings for the applicable new buildings and end uses compared to baseline buildings. Government inspections indicate that in a few dozen large cities, approximately 80% of residential buildings completed in 2008 complied with the applicable BEECs, compared with approximately 20% in 2005 and only 6% in 2000.[123] Although China has made great strides in building codes, the system of enforcement still needs improvement, particularly in smaller towns and rural areas.[124] Additional areas for improvement include closing loopholes in the system for testing building components, ensuring consistency of code compliance software, improving access to training and more user-friendly information, and developing increasingly stringent building codes.[125]

5.4.3 Zero-Net Energy Homes

A zero-net energy home combines a highly efficient building envelope, the most efficient appliances and lighting, and passive and active solar design features. Over the course of a year, a zero-net energy building (ZNEB) generates energy onsite in a quantity equal to or greater than the total amount of energy consumed onsite.[126] Chinese electricity consumption varies

121 http://www.ci.austin.tx.us/zoning/sf_regs.htm

122 China first attempted to mandate energy efficiency for buildings in 1986 when minimum energy-efficiency requirements for centrally heated new apartment buildings and associated heat supply systems were issued for trial implementation.

123 Feng, L., Meyer, A.S., and Hoga, J.F. Mainstreaming Building Energy Efficiency Codes in Developing Countries, Appendix 1. Case Study: Implementing Building Energy Efficiency Codes in China, World Bank, p. 93, 2010. Available at http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2010/11/16/000334955_20101116033507/Rendered/PDF/578770PUB0Main101public10BOX353783B.pdf

124 Evans, M., Shui, B., Halverson, M.A., and Delgado, A. Enforcing Building Energy Codes in China: Progress and Comparative Lessons, Pacific Northwest National Laboratory. August 2010. Available at http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19247.pdf

125 *Id*.

126 Zero Net Energy Buildings, State of Massachusetts, accessed 4/26/11. Available at http://www.mass.gov/?pageID=eoeeasubtopic&L=4&L0=Home&L1=Energy%2C+Utilities+%26+Clean+Technologies&L2=Energy+Efficiency&L3=Zero+Net+Energy+Buildings+(ZNEB)&sid=Eoeea

considerably by region. One source quotes a national average of 275 kWh per household in 2007,[127] whereas another gives an average of 525 kWh per Shanghai household.[128] China's household consumption is growing at a rate of approximately 10% per year.[129] Adding solar PV and assuring that the building envelope is as energy efficient as possible would help China meet its energy consumption targets and would reduce the quantity of coal used to provide electricity to Chinese homes and apartments.

Two cities, Austin, Texas, and Boulder, Colorado, have adopted ordinances that will require homes in these cities to be zero-net energy by 2015 and 2020, respectively. In Boulder, GHG emissions will be reduced 11% below 1990 levels and 40% below 2005 levels by 2020. Boulder residents also approved a measure in 2005 that dedicates a portion of property taxes to fund city sustainability efforts.[130]

The Pearl River Tower, located in Guangzhou, China and designed by Skidmore, Owings, and Merrill, is slated to be completed in 2011. It will be the first near net-zero energy skyscraper in China, through the integration of innovative building systems.[131]

5.4.4 Hook-up Fees for Building Developers

Inhibiting China's efficiency goals are the "split incentives" that characterize the building and construction sectors. Residential and commercial buildings are responsible for more than a quarter of China's total electricity consumption, and China builds an estimated 2 billion square meters of floor space annually. Yet under current electricity pricing practices, developers see little incentive to construct energy-efficient buildings or install energy-efficient end-use equipment, because less efficient materials, methods, and machinery have lower capital costs. They will not have to pay the higher operating costs of the lower-efficiency investments. Developers generally focus on completing construction quickly, minimizing investment, selling the units, and moving on to the next project. Energy efficiency is not a priority for them, and even significant increases in electricity prices would likely have little effect on building practices, at least in the near-term.

One way to overcome this market barrier is through hook-up fees, whereby developers are charged a one-time fee to connect to the grid. The fee would be related to the building's peak connected load, and could be higher for inefficient buildings and lower or even waived for buildings that meet stringent energy efficiency standards. This would then make energy efficiency applicable to developers in an economic

[127] Study on the Sustainability of Urban Household Energy Consumption in China. Bai Aizheng, Beijing Institute of Petroleum and Chemical Engineering, 2010. Available at http://www.seiofbluemountain.com/upload/product/201010/2010dthy05a10.pdf

[128] China Builds Huge 6.7 MW Solar Power Installation Next to High-Speed Rail. Daily Tech, July 22, 2010. Available at http://www.dailytech.com/China+Builds+Huge+67+MW+Solar+Power+Installation+Next+to+HighSpeed+Rail/article19104.htm

[129] Bai Aizheng, *Ibid*

[130] University of Wisconsin, Madison, Solid and Hazardous Waste Education Center. Available at http://www4.uwm.edu/shwec/zeronetenergy/pol_mun.html

[131] Pearl River Tower, Guangzhou China. Available at http://www.som.com/content.cfm/pearl_river_tower

sense, and encourage them to invest in energy efficiency.

5.5 Transportation

Like the building sector, transportation is fast becoming a major source of air pollution and GHG emissions worldwide. The transport sector is a significant contributor to GHG emissions in most countries; it is responsible for 23% of global CO_2 emissions from fossil fuel combustion in 2005.[132] Automobile transport is the principal CO_2 emitter, but other transport modes also impact global warming, sometimes significantly as in the case of aviation and maritime transport.[133]

In China, annual sales of on-road vehicles (excluding two-wheelers and rural vehicles) have grown from roughly 250,000 in 1980 to nearly 14 million in 2009. Annual sales of two-wheelers (including electric bikes) have grown from approximately 600,000 to a staggering 50 million plus. Recognizing this increase, in the last decade China has implemented a series of increasingly stringent vehicle and fuel standards, inspection and maintenance programs, and traffic restriction zones to improve air quality. As a result, despite the massive growth in vehicle stock and activity, China's vehicle emission control program has been effective in curbing conventional pollutant emissions.[134] Despite the emission reductions and concomitant health benefits achieved by the current program, however, continued improvements and more stringent policy measures will be required to mitigate the negative health and climate impacts of the significant projected growth trends in the vehicle market.

5.5.1 Fuel Efficiency Standards

The European Parliament's April 2009 regulation 443/2009 established EU-wide emissions performance standards for light-duty vehicles. The regulation's goal is to reduce GHG emissions 30% below 1990 levels by 2020. For new passenger cars, the initial emissions performance standard is set at 130 g/km, decreasing to 95 g/km in 2020. The regulation is applied to vehicle manufacturers, and includes a provision whereby the cleanest cars can earn compliance credits to offset emissions from cars whose emissions are cleaner than the levels of the performance standard. For example, each car made that produces CO_2 emissions of less than 50 g/km can be counted as 3.5 cars in 2012, decreasing to 1 car in 2016. Manufacturers can pool such credits among themselves. Penalties are assessed per gram of CO_2 per km, based on the average level of CO_2 emissions and the quantity of cars produced by the manufacturer that exceeds the performance standard.[135]

[132] OECD/ITF. Greenhouse Gas Reduction Strategies in the Transport Sector, Preliminary Report, iii, 2008. Available at http://www.internationaltransportforum.org/Pub/pdf/08GHG.pdf

[133] *Id*.

[134] According to the China Fleet Model (CFM), between 2000 and 2010, the cumulative emissions benefit of the current program over a "no program" scenario has been 44.5 million metric tons for total hydrocarbons (THC), 238.7 million metric tons for carbon monoxide (CO), 38 million metric tons for oxides of nitrogen (NO_X), and 7 million metric tons for particulate matter (PM).

[135] Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L2009:140:0001:0015:EN:PDF

Since the late 1990s, China has ratcheted down the emission limits for its major vehicle categories following the 'Euro' path, with major cities such as Beijing and Shanghai leading the way with accelerated adoption of standards. Although the time gap between standards in the EU and China has been closing, there remains a 4- to 5-year lag in adopting the newest standards. Introducing today's best available control technologies into the fleet will require implementing Euro6/VI level vehicle standards in the near term. This does not mean that China should simply retrace the path followed by the EU. China should seek to adopt the most advanced standards necessary and feasible whenever possible.[136]

5.5.2 Registration Fee Linked to CO_2 Emissions

Vehicle registration fees whose rates are scaled in proportion to the engine size or emissions can encourage consumers to purchase more fuel-efficient models. Higher fees for larger engine sizes also recognize the greater quantity of emissions and impacts to public health. The UK's vehicle taxes are tiered by the engine's size and its CO_2 emissions (g/km). The lower the CO_2 emissions, the lower the tax. Vehicles with CO_2 emissions of less than 100 g/km pay no tax, whereas those whose emissions are over 255 g/km pay the maximum rate of £425 per year.[137] Sweden's vehicle tax has a floor price of 360 Swedish kroner per year plus 15 kroner for each gram of CO_2 emitted above 100 g/km.[138]

5.5.3 Pay As You Drive (PAYD) Insurance

Automotive insurance premiums have traditionally been based on the age and gender of the driver, the type of car, and the driver's driving record, but not on the number of miles driven each year. Drivers pay similar premiums whether they drive 5,000 or 20,000 miles per year. Many countries and US states now offer car insurance based on the distance driven as an option to customers. This method of insurance coverage is referred to as Pay As You Drive, or PAYD, insurance. A Brookings Institution study concluded that PAYD could reduce driving in the United States by 8%, reducing CO_2 emissions by 2% and saving consumers an average of $270 per car per year.[139] A related Brookings Institution study completed to support a California PAYD initiative concluded that the CO_2 emissions saved from PAYD would be equal to 7 to 9% of California's 2020 GHG reduction goals. Additional consumer benefits cited included lower insurance premiums for two thirds of households,

---

[136] There are clear opportunities to "leapfrog" to China VI and even beyond, first in local jurisdictions where lower sulfur fuels (necessary for using the best available control technologies) are available and then nationally. For more information see Fung, F., He, H., Sharpe, B., Kamakate, F., and K. Blumberg. Overview of China's Vehicle Emission Control Program: Past Successes and Future Prospects. International Council on Clean Transportation, 2011. Available at http://www.theicct.org/2011/04/overview-vehicle-emissions-controls-china/

[137] http://www.direct.gov.uk/en/Motoring/OwningVehicle/HowToTaxYourVehicle/DG_10012524

[138] Overview of CO_2 Based Motor Vehicle Taxes in the EU. Available at http://www.uni-due.de/imperia/md/content/auto/vl_unterlagen/20070903_co2_tax_overview.pdf

[139] Bordoff, J.E., and Noel, P.J. The Brookings Institution. Pay-As-You-Drive Auto Insurance: A Simple Way to Reduce Driving-Related Harms and Increase Equity. July 2008. Note that the increase in US petrol prices to over $4 per gallon reduced consumption by 2 to 3%.

especially for low-income households, which tend to drive fewer miles.[140]

5.5.4 Multimodal Urban Planning

Urban development in several European cities emphasizes new development and modifications to existing buildings to create neighborhoods where residents live, work, and shop without relying on the automobile. These new urban neighborhoods also feature highly energy efficient buildings and structures on which solar PV panels are installed to provide electricity. Energy reducing features used in these developments include locally produced and recycled materials. They also combine energy efficient building design (including passive solar glazing) and onsite electricity generation (PV, biomass). The developments are also located on or close to bus, metro, and train connections, and well integrate the bicycle for both residential commuting and for errands and shopping.[141] Two notable projects are BedZed in London, England and Vauban, Germany.

5.6 Industry

In many countries, emissions from industrial sources contribute emissions comparable to those from the power sector, both in terms of relative volumes and source types. For China, approximately one third of coal combustion occurs at industrial plants, with electricity generation accounting for roughly 50%. In the EU and the United States, industrial sources comprise approximately one third of total criterion and GHG emissions, with transport and power sectors also contributing approximately one third each. Large industrial sources, such as cement and glass plants and pulp and paper mills have boilers on-site producing steam and electricity that can be equivalent in capacity to boilers used in the power sector. As a result, countries that have adopted emissions standards for the power sector often adapt those same standards for industrial sector emissions.

The EU and the United States have taken different approaches to regulating industrial sector emissions. In the EU, Directive 2001/80/EC applies to all (new and existing) combustion plants with an input capacity greater than 50 MW, regardless of the type of fuel used. It requires both specific plant-by-plant compliance and total emissions reduction (analogous to China's concept of total emissions control). This directive was highlighted in the best practices section previously. The 2001 EU Large Combustion Plant Directive (LCPD) establishes limits for SO_2, NO_X, and dust (PM_{10}).

For each EU member state, Annex 1 of the LCPD establishes emissions ceilings for SO_2 (in kilotonnes per year), the percent emissions reduction required for each of the three phases of emissions standards (compared to a 1980 baseline), and the percent emissions reduction compared to an adjusted 1980 baseline. Inner EU countries, such as the United Kingdom, Belgium, France, Germany, and the Netherlands, are subject to emissions ceilings that require a 70% reduction in SO_2 emissions by phase 3. Newer EU member states such as Greece, Ireland, and Portugal

[140] Bordoff, J.E., and Noel, P.J. The Brookings Institution. The Impact of Pay-As-You-Drive Auto Insurance in California. July 2008.
[141] State of the World 2010. Transforming Cultures: From Consumerism to Sustainability; Worldwatch Institute, Washington, DC. The Vauban, Germany, development was featured in the New York Times, May 11, 2009. "In German Suburb, Life Goes on Without Cars."

were allowed to increase their emissions in real terms compared to the 1980 baseline.[142] Annex II of the LCPD establishes specific emissions and percent reduction requirements for each member state's NO_X emissions. New sources are subject to specific concentration-based standards for SO_2, NO_X, and dust, whose stringency increases proportionately to the emissions unit's capacity. No emissions ceilings were established for dust.

The EU's Integrated Pollution Prevention and Control (IPPC) Directive 2008/1/EC complements the LCPD by requiring the application of "best available techniques" at each affected facility.[143] The Directive's emphasis on pollution prevention requires affected sources to think about the processes used at their enterprise, and to use techniques and materials that minimize total waste and energy consumption. As such, the IPPC Directive is an upstream regulatory approach that helps to reduce criterion, GHG, and toxic emissions, deferring consideration of the installation of end-of-pipe controls until after the best waste prevention practices are first used. If the waste prevention review is performed properly, and end-of-pipe controls are still needed to meet national emissions ceilings or concentration-based effluent limits, such controls should be smaller and less expensive to install and operate than would be the case if the review process had not emphasized a holistic approach or focused on specific emissions points.

The IPPC Directive covers 52,000 industrial facilities in the EU, and includes GHG emissions, except for those facilities already subject to the EU emissions trading scheme. Decommissioning or plant closure activities are also subject to review. Member states are required to submit reports to the European Commission regarding IPPC Directive implementation.

The EU emphasizes source-by-source and total emissions reductions on a *mass* (tons) basis, whereas the United States emphasizes the ability of standards to reduce pollutant *concentrations.* In the United States, New Source Performance Standards (NSPSs) establish specific *input-based* emissions standards for NO_X, SO_2, and opacity (a measure of visual pollution emitted from a stack) based on the size of the boiler. NSPSs were first applied to large boilers greater than 100 MMBtu/hr in 1986, with subsequent NSPS issued for boilers whose capacity exceeded 10 MMBtu/hr. As the name implies, NSPSs focus on emissions from new plants, or those that have undergone significant modifications.

Consistent standards for existing industrial sources are not applied throughout the United States.[144] Rather, in areas where air quality exceeds applicable ambient air quality standards, states and municipalities

[142] IPPC Directive 2001/80/EC. Available at http://europa.eu/legislation_summaries/environment/air_pollution/l28028_en.htm 23 October 2001. Note that combined emissions from Greece, Ireland, and Portugal even when allowed to grow are less than one half the emissions from a single member state like the United Kingdom or Spain.

[143] IPPC Directive 2008/1/EC. Available at http://europa.eu/legislation_summaries/environment/waste_management/l28045_en.htm Codified version 15 January 2008.

[144] Few if any US industrial boilers have been fitted or retrofitted with flue-gas desulfurization (FGD). Research completed for a report on mercury controls for the EPA could not locate a single instance of FGD applied to a US industrial boiler. Telephone conversation with Praveen Amar, NESCAUM, July 13, 2010.

are required by the EPA to apply minimum levels of emissions controls to existing sources, based on their source category. The EPA developed guidance documents that assess the type of technologies that can be applied to reduce emissions at a reasonable cost. States are in turn required to use these minimum standards to determine their ability to reduce ambient concentrations of the pollutants to levels that meet or are below those needed to attain the applicable ambient standard.

5.6.1 Industrial Ecology

Industry ecology is a theory of industrial organization that seeks to minimize waste and optimize resources by shifting from the predominate technique of linear production streams to closed loop systems that use the waste products of one process as inputs to other processes. Industrial ecology focuses on optimizing energy and material resources and capital investments across industrial sectors and enterprises to harmonize economic and environmental objectives at large. Industrial ecological techniques can significantly reduce air emissions and energy use.

Life-cycle material and resource planning can be effectively coordinated between businesses at specialized eco-industrial parks. One such park, a large and sustained industrial ecology project, is located in Kalundborg, Denmark. The project began in 1972; the number of participating facilities and the level of materials exchange has been expanded several times, and now exceeds 3 million tons annually. Process facilities located at this site include a power plant, refinery, wallboard factory, and municipal wastewater treatment plant. The symbiotic processes at Kalundborg use "waste" from one facility as part of the input feedstock for another. Steam from the coal-fired power plant is used at a refinery and to heat a fish farm. Cooling water from the refinery is then used at the power plant. Sulfur from the refinery is an input to fertilizer production. The power plant also provides district heating for the town, eliminating the need for 3,500 domestic oil-fired boilers. Gas from the refinery is used at the wallboard factory, a step that reduced oil consumption by more than 90%.[145]

In North America, Dalhousie University's Eco-Efficiency program has worked with the City of Halifax, Nova Scotia, to establish the Burnside eco-industrial park in that municipality. To date, over 1,500 businesses, totaling more than 15,000 employees, have established operations in the park. Dalhousie has worked with Burnside businesses since 1998 to improve their environmental performance and to facilitate materials exchange among and between businesses located in the park.[146]

5.7 Appliance and Equipment Standards

Home appliances are the world's fastest-growing energy consuming devices after automobiles, accounting for 30% of industrial countries' electricity consumption and 12% of their GHG emissions. In

145 http://www.bsdglobal.com/viewcasestudy.asp?id=77. See also http://en.symbiosis.dk/industrial-symbiosis.aspx (includes graphic of all interconnected industrial processes).

146 Dalhousie University, Eco- Efficiency Centre, Halifax, Nova Scotia, http://eco-efficiency.management.dal.ca/About_Us/History.php

developing countries the potential for appliance growth is staggering: sales of frost-free refrigerators in India alone are projected to grow nearly 14% annually. Improving the efficiency of appliances used in homes therefore has the potential to dramatically reduce energy consumption and CO_2 emissions.[147]

China has implemented a series of minimum energy performance standards and has expanded the coverage of its voluntary energy efficiency label to over 40 products, including residential, commercial, and selected industrial products. Since 2005, household refrigerators and air-conditioners have been required to display a mandatory information label with the expectation that clothes washers will be added to the program. For measures in place as of 2007, China is expected to save a cumulative 1,143 TWh by 2020, or 9% of the cumulative consumption of residential electricity to that year. In 2020 alone, annual savings are expected to be equivalent to 11% of residential electricity use. In average generation terms, this is equivalent to 27 1-GW coal-fired plants that would have required approximately 75 million tons of coal to operate.[148] China can improve annual savings by making MEPs mandatory and further expanding the products covered under the MEPs.

In the United States, energy consumption standards for appliances are set by the US Department of Energy. They were not initially thought to be a policy that could be included in climate-friendly air quality plans. Like the tailpipe emissions standards for vehicles, however, California and other US states have adopted standards for appliances and equipment that require lower energy consumption than those of their federal equivalents. The EPA's air quality models assume that the energy consumption effects of national level standards are reflected in the observed generating output used to forecast future electricity growth and air pollution. States that adopt standards requiring lower energy consumption for appliances, however, can take credit in their air quality plans for the resulting differences in criterion and GHG emissions that will occur.

A report prepared for the Texas State Energy Conservation Office by the American Council for an Energy Efficient Economy (ACEEE) concluded that adopting standards that required more efficient products would reduce CO_2 emissions by 1.643 million metric tons, NO_X by 996 metric tons, and SO_2 by 2,774 tons by 2020.[149] These are substantial emissions reductions; regulators in states whose air quality violates ambient standards have implemented control measures whose reductions can be measured in fractions of tons per day and can have costs that exceed $10,000 per ton of pollution reduced.[150]

---

[147] Lawrence Berkley National Laboratory, Appliance Standards. Available at http://eetd.lbl.gov/l2m2/standards.html

[148] Fridley, D., Aden, N., Zhou, N., and Lin, J. Impacts of China's Current Appliance Standards and Labeling Program to 2020. Lawrence Berkeley National Laboratory, 2007. Available at http://china.lbl.gov/publications/impacts-chinas-current-appliance-standards-and-labeling-program-2020

[149] Eldridge, M. et al. Opportunities for Appliance and Equipment Efficiency Standards in Texas. American Council for an Energy Efficient Economy (ACEEE), September 2006, Report Number ASAP-7/ACEEE-A063.

[150] For example, the state of Maryland was considering several control measures to help reduce

The US Department of Energy's Appliances and Commercial Equipment Standards Program develops test procedures and minimum efficiency standards for residential appliances and commercial equipment. The Program develops rules and regulations that manufacturers must adhere to in manufacturing products. These regulations apply to products manufactured for sale in the United States as well as those imported into the United States. The minimum energy efficiency standards require manufacturers to discontinue manufacturing products that do not meet the efficiency standards. Products manufactured prior to the effective date of the standard, however, may still be sold.[151]

5.7.1 ENERGY STAR Appliance Rebate Program

ENERGY STAR is a joint program of the EPA and the US Department of Energy. The program approves products, including appliances, as well as homes, home improvement techniques, and energy management strategies for business and commercial buildings that meet a certain standard of energy efficiency.[152] In 2010, each state and US territory participated in the ENERGY STAR appliance rebate program. Each state and territory designed its own rebate program, and all 56 plans were approved by the US Department of Energy. Customers who purchased ENERGY STAR appliances during calendar year 2010 were eligible for rebates through their respective state or territory. As of December 31, 2010 a total of 1.4 million customer rebates were paid to customers. The annual energy savings resulting from the purchase of the rebated products is estimated at 1.4 trillion Btu. These rebates included major appliances (89%), HVAC systems (9%), and water heaters (2%).[153]

5.7.2 Negotiated Performance Agreements

As an alternative to directing monetary incentives for energy efficient products at the point of sale, state efficiency program administrators and some countries have negotiated directly with equipment and appliance manufacturers and suppliers to guarantee that a specific quantity of high-efficiency products be sold in targeted areas. In these cases, the financial incentives are applied upstream to help buy down the differential purchase price between an efficient and conventional product. Such a strategy uses funds more efficiently and helps to transform the market for more efficient products. Additionally, it reduces administrative and processing costs as compared to point-of-sale rebate type programs in which a consumer fills out a card and returns it to the utility to receive a rebate check.

emissions to attain the ambient ozone standard: purchase of wind energy renewable energy credits ($32,000 per ton of emissions reduced per year), CNG refueling stations ($54,701), and 55 CNG buses ($103,063). Ann Elsen, Energy Planner, Montgomery County, Maryland; presentation "Policy Challenges and Opportunities" to Maryland Wind Working Group, March 18, 2005.

[151] US Department of Energy, Appliances and Commercial Equipment Standards. Accessed April 27, 2011. Available at http://www1.eere.energy.gov/buildings/appliance_standards/

[152] US EPA and US DOE, ENERGY STAR. Accessed April 27, 2011. Available at http://www.energystar.gov/index.cfm?c=about.ab_index

[153] US DOE, Rebates for ENERGY STAR Appliances. Accessed April 27, 2011. Available at http://www.energysavers.gov/financial/70020.html

As with the approach to appliance and equipment standards discussed previously, air quality and energy regulators will need to assess the differences in sales between the two business models, and assuming the upstream business model had increased product sales, the quantity of criterion and GHG emissions displaced could be accounted for in criterion and GHG reduction plans.

6. Technical Practices for Climate-Friendly Air Quality Management

As mentioned in the introduction, two areas that require careful consideration in climate-friendly air quality plans are:

- The technical modeling tools that are used to evaluate the energy, environmental, and economic attributes of policy measures that can be implemented to reduce pollution; and
- The sequencing of emissions control and monitoring equipment installed to capture criteria pollutants and measure effluence concentrations.

Assessing ambient air quality and emissions inventory data is also a critical component to the iterative air quality planning process. Its characteristics, however, are not distinguished between traditional and climate-friendly air quality management, so this section will only briefly identify "best practices" to reinforce the point that data assessment is crucial, but that there are no essential differences between such practices whether they are conducted as part of traditional regulatory practices or climate-friendly air quality management.

6.1 Technical Tools

Environmental, energy, and economic models help scope the range of policies that can be implemented to achieve desired agency objectives. Models can be primary or derivative. A ***primary model*** is one that permits user-defined inputs for dozens of economic, environmental, and energy variables. A primary model lets users choose data for variables that include equipment costs, fuel costs, meteorologic conditions, discount rates, load zones where energy efficiency measures are installed, and stringency of building codes. A ***derivative model*** is typically a spreadsheet tool, the structure of which is based on the outputs of a primary model.

6.1.1 Benefits of Derivative Models/Spreadsheet Tools

Spreadsheet tools contain default assumptions for many values used in primary models, such as equipment costs, fuel costs, and discount rates, but they let the user input data from a narrow set of variables, such as a building's particular electricity or fuel consumption.

Spreadsheet tools used by policy makers today include the EPA's Portfolio Manager[154] and ICLEI's Clean Air and Climate Protection Software (CACPS).[155] Portfolio Manager allows users to first benchmark and then to assess their energy and water consumption. Buildings with low scores can be prioritized for efficiency

[154] More information about the EPA's Portfolio Manager can be found online at http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

[155] For more on ICLEI's Clean Air and Climate Protection Software, see http://www.icleiusa.org/action-center/tools/cacp-software. There are dozens of spreadsheet tools and calculators used today. Reference to Portfolio Manager and CACPS is not intended to be an exhaustive list, but to simply describe the existence of such tools.

improvements and/or building operator training. The CACPS calculates emissions of GHG and local air pollutants from the energy sector, fuel use, and waste disposal.

Spreadsheet tools supplement, but do not substitute for, primary models. The output from spreadsheet tools typically does not withstand criteria that meet regulatory standards. Spreadsheets, however, are very easy to use, require little training or advanced modeling skills, and can be used by agencies to quickly identify and screen policy measures that appear to have substantial environmental, economic, and energy benefits. The effects of the screened measures can then be more fully analyzed and evaluated with primary models.

6.1.2 Benefits of Primary Models

Although the cost-effectiveness of policies is one desirable outcome, primary models ("models") also help agencies to assess the benefits and costs of policies being considered across a range of reductions and timeframes. Models play a routine role in US and EU environmental policy evaluation, but agencies do not rely on models alone to make informed decisions or to take effective actions to reduce public health and environmental impacts. It is easy to become trapped in "paralysis by analysis," seemingly endless and iterative evaluations of slight differences among many possible policy choices, without taking steps to act upon any of them. Models are most effectively used to examine boundary impacts, that is, what are the maxima and minima effects that could result from implementation of a given suite of policies?

The precision of models has greatly improved over the past 20 to 30 years. Some analysts demonstrate this improved precision by using actual data to "back-cast" what has occurred in the period previous to the present to show, by demonstrating its historical accuracy, how precisely a model can predict the future. All models have limitations and their use needs to be tempered by the facts "on the ground."

Evaluating how various concurrent control measures affect multiple pollutants and how these multiple pollutants may interact with one another is complex. Numerous technical models may be used in tandem to analyze an integrated policy framework. Today this kind of analysis generally involves four different types of models:

- **Air quality models** evaluate impacts of policies on pollutant concentrations. Examples of air quality models include: CMAQ[156], regional scale; ISC, source specific impact; CAL PUFF[157], for long-range transport of pollutants and for complex meteorological conditions.
- **Economic models** use the outputs from an air quality model to assess the cost effectiveness of policies and to identify least-cost policies. Examples of economic models include the Regional Economic

[156] The Community Multi-Scale Air Quality model, or CMAQ, was developed by the University of North Carolina. It is an open-source modeling project conducted in conjunction with the US EPA. For more information, see http://www.cmaq-model.org/

[157] CAL PUFF was developed by Sigma Research Corporation while under contract to the California Air Resources Board. The model has been adopted by the EPA and is currently maintained by the Atmospheric Research Group at TRC. More can be found about it online at http://www.src.com/calpuff/calpuff1.htm

Model, Inc. (REMI),[158] MARKAL,[159] and the Long-Range Energy Alternatives Planning System (LEAP).[160]

- **Energy models** also use outputs from an air quality model and calculate potential effects on generators. Examples of energy models include IPM, ProSym, Strategist, and Monte Carlo technique.
- **Public health models** determine baseline effects using current conditions as input (emissions inventory) and assess potential benefits from policy choices. Examples of public health models used in an integrated policy framework include the Environmental Benefits Mapping and Analysis Program (BenMAP) and the co-benefits risk assessment model COBRA.

Two examples of how models are being used to design, develop, and assess a comprehensive set of policies are described next: one in the Northeastern states and one in China.

[158] Regional Economic Model, Inc., or REMI, was developed and is maintained by REMI in Amherst, MA. More at www.remi.com.

[159] MARKet Allocation model was originally developed by Energy Technology Systems Analysis Program (ETSAP) of the International Energy Agency. MARKAL is used by the UN Framework Convention on Climate Change for compliance. NE-MARKAL (for Northeast MARKAL) developed by NESCAUM is currently loaded with data for 12 northeastern states. More about MARKAL can be found at http://www.etsap.org/markal/main.html. More about NE-MARKAL is online at http://www.nescaum.org/topics/ne-markal-model

[160] Long-range Energy Alternatives Planning System (LEAP) was used by the Stockholm Environmental Institute (SEI) to assess how China might transform its energy system and maintain its rate of economic growth. Charlie Heaps, SEI. A Deep Carbon Reduction for China. May 24, 2009. Available at http://www.energycommunity.org/documents/DCRSFinal.pdf. More information online at http://www.energycommunity.org/default.asp?action=47

6.1.3 NE-MARKAL, REMI, and CMAQ in the Northeastern United States

Figure 2 describes an integrated modeling framework that is being used by Northeastern states in the United States to evaluate multi-pollutant benefits.[161] The framework has three main components: air quality, energy, and economic.

An energy model, MARKAL, is used to evaluate the emissions benefits from a policy or set of policies. MARKAL evaluates policies based on user-selected inputs on the degree of emission reduction required. MARKAL requires the user to input baseline information about the current and expected future energy demands for the state or region being evaluated. Based on the energy system and environmental goals required, MARKAL will select the most cost-effective policies to meet the energy and environmental goals.

Outputs from the MARKAL model are the level of emissions reductions and the costs of those reductions. The emissions reductions become inputs to the CMAQ air quality model, and the policy costs become inputs to the REMI economic model. CMAQ is intended to be used to analyze policies that affect several air pollutants and over many different scales, from local (at the scale of a single city or urban area) to regional (encompassing several states). The CMAQ model evaluates the effects of the emissions reduced on ambient air quality concentrations, based on varying meteorological conditions over short- and long-term averaging periods. CMAQ can

[161] NESCAUM. Integrating Climate and Air Quality Planning in Maryland; Applying NESCAUM's Multi-pollutant Policy Analysis Framework. March 20, 2009.

evaluate interactions between air pollutants, including ground level ozone, regional haze, and air toxics. CMAQ also provides output data for wet and dry deposition, which in turn can help assist water quality regulators, natural resources managers, and regional scale analyses of air quality programs designed to reduce the effects of acid rain.

REMI is an econometric model that determines the change in economics by sector due to the implementation of one or more proposed policies. REMI is also described as a general equilibrium model, meaning that traditional supply and demand policies are considered optimal in terms of maintaining economic growth and output. Based on user-defined policy changes, the REMI model outputs include the number of jobs, differences in tax revenues, and effect on gross state product.

In Figure 2, the BenMAP[162] model is used to determine the public health benefits from the implementation of the proposed policies. These benefits include morbidity and mortality (number of cases of asthma, hospital admissions, heart attacks) and the value of those benefits. BenMAP is preloaded with the same values that the EPA uses to assess the potential benefits of proposed air quality standards.

Each of the model's variables can be manipulated. The modeling exercise can be

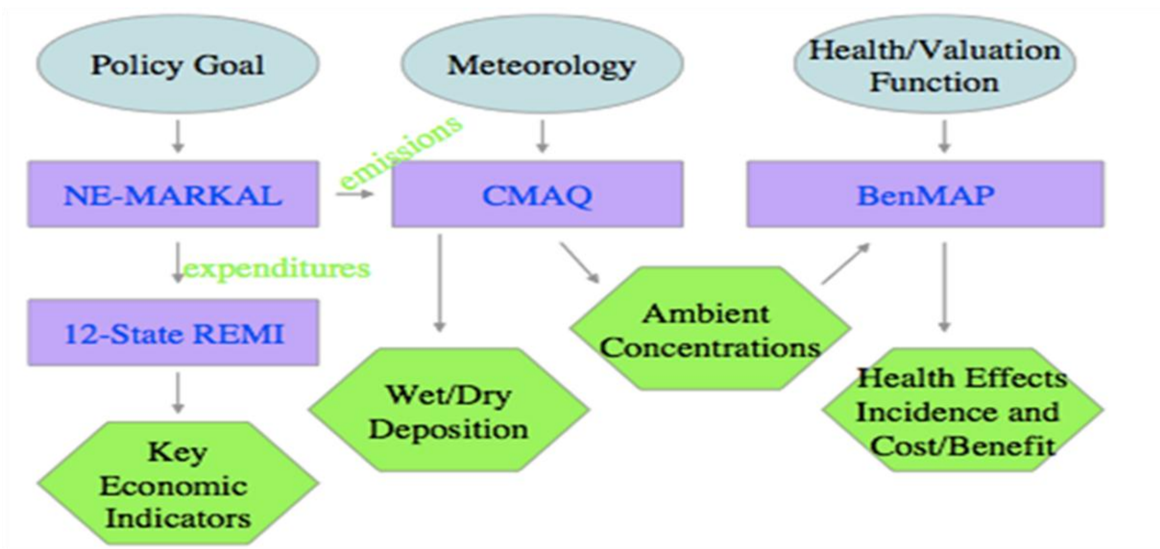

Figure 2. The multi-pollutant modeling framework used by NESCAUM, the voluntary association of air quality agencies in the northeast United States, to analyze multi-pollutant planning efforts at the state level. The analysis framework uses economic, energy, and air quality data in an integrated fashion.

[162] Environmental Benefits Mapping and Analysis Program model, BenMAP, is now hosted at the University of North Carolina (as is CMAQ). More information is available at http://www.benmap-model.org/

iterative. A particular policy may be insufficient to reduce emissions adequately to meet in a timely fashion the required ambient air quality concentrations, or it may in fact meet or exceed the desired environmental goals, but at too high a cost. Multiple model runs are made at varying degrees of policy penetration to determine the influence of a particular set of variables on the desired environmental outcome.

This framework does not include an assessment of energy sector effects from the proposed environmental policies. There are two possible mechanisms to assess such effects. First, the outputs from MARKAL are used as inputs to an energy sector model. The relevant MARKAL outputs would be the costs of any emissions controls that would be required on power plants and the proposed quantity of energy efficiency and/or renewable energy development. Electric system dispatch modeling can evaluate how the operations of units that install emissions controls (and therefore have higher variable costs) will change. It will also quantify the effects of increased energy efficiency and renewable energy development on existing generation.

6.1.4 LEAP Model and China

The Stockholm Environmental Institute (SEI) has applied the LEAP model to evaluate—from an energy perspective—those policies that can jointly reduce local air pollutants and GHGs. LEAP's platform is flexible enough to accommodate any user-defined energy sector structure. SEI and the China Economists 50 Forum used LEAP to analyze development scenarios for China that simultaneously improve economic growth and maintain GHG emissions at a level that does not result in a global temperature increase of more than 2° Celsius.[163] The report describes scenarios that would result in China's per capita income growing 800% by 2050 from current levels. Reducing GHG emissions 80% by 2050 was also evaluated. Although the rapid economic growth makes meeting this reduction goal a substantial challenge, aggressive energy efficiency measures in all building types, industrial processes, and fuel combustion would provide over half of the GHG reductions by 2050. These include using building design to exploit maximum heating and cooling opportunities (e.g., passive solar building designs and CHP), retrofitting of older buildings, and adoption and enforcement of building codes and appliance standards.

The US Lawrence Berkeley National Lab has also used the LEAP model to evaluate climate-friendly air quality management strategies, specifically analyzing optimized co-control strategies for meeting China's dual goals of reducing carbon intensity and SO_2 emissions. This report is forthcoming.

6. 6.1.5 Greenhouse Gas and Air Pollution Interactions and Synergies

Another way in which energy sector models are used in an integrated modeling framework is to first run an energy sector model, as constrained by the proposed environmental policies. The energy sector models also provide economic output, the difference in the costs of generation, which can then be used as input to REMI.

[163] Stockholm Environmental Institute. A Deep Carbon Reduction Scenario for China: China Economics of Climate Change Initiative. May 24, 2009. Available at http://www.energycommunity.org/documents/DCRSFinal.pdf

The Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)[164] model has been extensively used in Europe and several Asian countries to evaluate policies that reduce both GHG and conventional air pollutants. GAINS is an extension of RAINS,[165] which evaluates interactions between air pollution and policies, but did not include GHGs. GAINS and RAINS include economic and environmental modules in which emissions controls are applied to various economic activities to determine their effects on pollutants. Like CMAQ, GAINS and RAINS also provide multi-pollutant assessments and acid deposition and eutrophication effects from air pollutants. And like MARKAL, GAINS and RAINS can simultaneously provide the lowest cost solutions to achieve the desired air pollutant standards. Energy use is an input to GAINS and RAINS, but changes to electric sector resources, such as differences in generator output, are evaluated separately using electricity dispatch models. Economic and environmental effects from new energy efficiency or renewable energy policies can be determined by developing multiple scenarios. One attractive feature of GAINS and RAINS is the ability to adjust emissions control costs to account for regional differences.

6.2 Emissions Control and Monitoring Equipment

We conclude with a discussion of best practices for emissions control and monitoring equipment. We do not cover the selection, design, and operation of such equipment; those are well covered in manuals and guidance published by the EPA, the Air and Waste Management Association, and other like organizations around the world. Rather, we emphasize here the advantages of evaluating pollution-control equipment and the analysis of data from ambient air quality and stack monitors through a climate-friendly lens, and the benefits of so doing.

Agencies that consider the application of pollution-control equipment and evaluate data from air quality and continuous emissions monitors from climate-friendly perspectives will realize that:

- Pollution-control programs need to be designed such that technologies and processes are sequenced to reduce emissions of all pollutants (local, toxic, regional, and GHGs). Such an approach permits air quality to be improved by changes in industrial processes, end-use energy efficiency that reduces the energy intensity and consumption, and, where appropriate, end-of-pipe emissions controls.
- There are potential trade-offs between pollutants so that agencies can optimize control strategies and prioritize reductions in terms of their public health benefits.
- A multi-pollutant regulatory framework can provide certainty to businesses and industries, so that they can optimize capital investments and improve operating processes to meet current and future

[164] GAINS, Greenhouse Gas and Air Pollution Interactions and Synergies, was developed by the International Institute for Applied Systems Analysis (IIASA). More information at http://www.iiasa.ac.at/rains/gains/documentation.html

[165] Regional Air Pollution Information and Simulation (RAINS) was also developed by IIASA.

expected standards. Businesses can make investments with long-term planning horizons and avoid having to retrofit emissions control equipment into constrained spaces.

- Data from point-source monitors (i.e., CEMS) and ambient air quality monitors can be fully integrated into air quality plans to assess the efficacy of control measures from a sound scientific basis. Continuous emissions monitors provide agencies with real-time data that informs emissions inventories and measures progress toward reducing air pollution. Ambient monitoring data informs agencies with regard to the efficacy of their control measures and can isolate local or regional influences to air pollution that may require additional attention. After co-control programs are implemented, agencies should review ambient monitoring data to determine what pollutants are changing, the degree of change, and their geographic location. For NO_X reductions to be achieved under the 12^{th} Five-Year Plan, both VOC and NO_X will have to be reduced to reach the NO_X reduction goals and attain Grade II standards for O_3 and fine particles. Reducing NO_X alone will not change O_3 concentrations, and may increase them downwind of China's urban areas.

The following subsections describe how pollution-control equipment choices can be made to leverage emissions reductions and how data from emissions monitors using a climate-friendly perspective influence the choice of monitors and applications for their data.

6.2.1 Pollution Control Equipment

Multi-pollutant air regulation strategies will have implications for technical investment decisions at the facility level. Broad policy translates into concrete action at the facility level. When facility owners develop an integrated air pollution control strategy, they can configure the control equipment to optimize the reductions of multiple pollutants. For example, an electrostatic precipitator (ESP) upstream of the air pre-heater ("hot side") effectively reduces particulates, but has almost no effect on mercury emissions. By contrast, an ESP downstream of the air pre-heater ("cold side") provides similar particulate control while also reducing mercury by 30 to 40%.

As distinguished from a pollution-control strategy that accounts for only current pollution standards, a multi-pollutant approach to equipment selection in China would recognize that:

- Ozone is being added to the ambient air quality standards (draft ambient air quality standards, GB 3095-2010 were released for public comment in November 2010);
- Fine particulate matter will soon be regulated, first in key regions;
- Air toxics, such as mercury, will be regulated in the 12^{th} Five-Year Plan, and pilot projects are already underway; and
- China's goal to decrease carbon intensity 40 to 45% by 2020 will require reductions in GHG emissions.

These factors will affect pollution control equipment decisions. On the other hand, if agencies approach air quality planning on a pollutant-by-pollutant basis, companies will invest in equipment to meet specific pollutant reduction requirements, but the equipment chosen may not reduce other pollutant emissions and may even increase them. In addition, the pollutant-by-pollutant approach may cause an increase in the emissions of pollutants not currently regulated or may cause technical challenges to their control in the future.

A climate-friendly approach to pollution-control equipment counsels a review of industrial processes themselves and of how the processes can be improved to avoid or reduce the size of end-of-pipe pollutant controls. This discussion assumes that a decision has already been made to install pollution controls and that measures to improve end-use efficiency at the enterprise- or customer-level have already been taken or are in the process of being implemented. We distinguish between pollution controls installed on existing sources and those installed on new sources. To illustrate why climate-friendly air quality planning can provide superior environmental results at equal or lower costs, we look to the lessons learned from the US control of emissions from the power sector.

For existing sources, pollution controls should be sized and their installation sequenced from a multi-pollutant perspective, even if the controls themselves may be phased in or staged over several years. This means that adequate space should be made to accommodate equipment sized to represent the best possible emissions controls for NO_X, SO_2, particulate matter, and mercury. For example, cost and timing considerations may dictate that, initially, selective catalytic reduction (SCR) technology to reduce NO_X emissions at power plants and industrial sources achieve only a 70% reduction, rather than the 90+% that is possible. When the SCR equipment is installed at the enterprise, however, the physical equipment itself should be sized to accommodate a 90+% NO_X reduction by placing adequate cells on site. The cells may be filled with sufficient catalysts to achieve only a 70% reduction, but later when, as typically happens, environmental agencies realize that additional reductions are necessary to achieve environmental targets (especially in the face of significant economic growth), the vacant cells can be easily filled with catalysts. This same approach can be applied to technologies that reduce SO_2, particulate matter, and mercury. In the case of particulate matter for example, a fabric filter could be sized to capture 98 to 99% of the particulates, but at first it may be necessary to install only enough bag filters to achieve a 95% reduction (a few cells could be left empty). This sequencing would also aid in mercury emissions control as fabric filters are installed downstream of activated carbon injection technologies.

China's experience with flue gas desulfurization (FGD) illustrates why climate-friendly multi-pollutant approaches are preferable. China's decision to require SO_2 reductions resulted in FGD installations at many power plants. These FGD were designed to achieve modest reductions (i.e., not the 95% reductions that are possible). After several years of operation, China realized that additional SO_2 reductions were going to be necessary to meet SO_2 and acid rain goals, and many existing FGD facilities had to be ripped out entirely and replaced with new and more effective emissions capture technology.[166]

For new sources, the same design principles apply, with one more: new sources should also be as thermally efficient as possible.

[166] Personal conversation, Jeremy Schriefels, US EPA, April 25, 2011.

Such an approach will help to assure that the least amount of fuel is used to produce a unit of electricity or production, thus making the boiler itself smaller for the same annual generation or production as an existing facility. Then the emissions controls are sized to meet the smaller boiler size, and are less expensive to build and operate. New sources should also have the best possible emissions controls installed when operation is commenced, as a condition of their receiving approval to construct.

The NO_X and SO_2 emission reduction targets in China's 12th Five-Year Plan are ambitious. China's success at closing small, outdated power plants and factories during the 11th Five-Year Plan will make the 12th Five-Year Plan goals a challenge, especially when China's economic growth is factored into the amount of emissions reductions that are required to be achieved from a business-as-usual projection. It took the United States two decades to achieve similar NO_X reductions, which were achieved in conjunction with aggressive policies that also reduced VOC emissions. Reducing NO_X emissions 10% and achieving an additional 10% reduction in SO_2 emissions by 2015 are possible if best practices in emissions control equipment are combined with policies that also ensure that energy is used efficiently across all sectors—residential, commercial, and industrial.

SCR technologies are one of the many that China is considering to require at power plants and industrial facilities to meet the 12th Five-Year Plan NO_X reduction goals. The SCR footprints at each installation should be designed to accommodate technologies that are sized to achieve a 90+% reduction. If costs or timing are issues that preclude installation of the best technology now, the SCR equipment that is actually installed can be configured so that catalyst modules are not inserted in some sections. Catalyst modules can be installed in the remaining parts of the control device to allow a more modest goal (e.g., 70%), if this is the preferred initial policy approach. Making sure that the initial SCR is designed and installed so that it can later accommodate catalyst modules to achieve greater reductions will avoid the need to remove sections or whole emissions devices later, a very expensive and time-consuming process that slows down the rate at which emissions reductions can be achieved.

US experience strongly suggests that China should undertake policies whose effects are to concurrently reduce VOC and NO_X. In urban areas, NO_X helps to scavenge ozone (O_3) locally, resulting in increased O_3 concentrations downwind of these urban areas. Removing NO_X without also removing VOCs at the same time could actually increase O3 formation. NO_X and oxygen react to form an oxygen radical, which in turn reacts with oxygen to form O_3. But O_3 and NO react to form oxygen and NO_2. Little O_3 is formed by these reactions. When VOCs are added, the O_3 and NO reactions are bypassed, and more oxygen radicals are formed. If China's 12th Five-Year Plan reduces only NO_X, O_3 concentrations would be expected to rise, and likely by significant amounts downwind of China's urban centers. So, although VOC reductions are not an explicit goal of the 12th Five-Year Plan, VOC reductions should be accorded equal footing in developing plans that also reduce NO_X to achieve China's air quality goals.

6.2.2 Emissions Monitors

A multi-pollutant framework would likewise steer investment in CEMS toward more reliable and incrementally less expensive technologies. Enterprises considering SO_2 requirements singularly, for example, are more likely to invest in *in situ* (i.e., in-stack) monitors. This is the trend in China today where approximately 50% of industrial facilities and power plants outfitted with CEMS use *in situ* monitors. These monitors may be less expensive initially, but due to complicated maintenance and calibration requirements, they tend to produce much less accurate data than the alternative, an extractive technology that draws a sample away from the flue to analyze it. The extractive technology may be more than double the cost of *in situ* monitors due to first-time infrastructure modifications. With one extractive CEMS already installed, however, the incremental cost of additional monitors is minimal, approximately $10,000 per monitor as compared to $120,000 for additional *in situ* monitors, while accuracy can reach ±2.5% and reliability 99%, as levels do in the United States. Given the right signals, enterprises can make the planning and investment decisions best suited to meeting current and future requirements cost-effectively.

Air quality control measures should be designed and implemented with the intention that they will be effective all day, every day. Policies that are in place year-round reduce baseline pollutant concentrations, which in turn help keep the level of peak concentrations lower than it would have been in the absence of the measures.

SO_2 and NO_X emissions monitors are important indicators of compliance with air pollution regulations and as a means to account for the tons of pollutants reduced. From a climate-friendly perspective, a CO_2 emissions monitor installed on power plants and large industrial sources enables effective and efficient fuel combustion techniques to be deployed to ensure that each unit of fuel combusted works as hard as possible to make a unit of electricity or production. End-use improvements in combustion can reduce fuel consumption by 1 to 3%, and the effects of changes made are best learned from CO_2 monitors. A 1 to 3% improvement may seem modest, but at power plants and industrial processes that burn millions of tons of coal each year, a 1 to 3% reduction means significant fuel savings, reduced emissions of NO_X and SO_2, and extended lives for pollution control equipment.

7. Conclusion

For professionals accustomed to developing air quality plans, a climate-friendly planning framework may at first seem to be merely an approach whereby policies to effect reductions in GHG emissions are layered onto policies already in place to reduce local and toxic air pollutants. This is not the case. Simply adding GHG emissions to current air quality policies would maintain the siloed approach to air quality management that has successfully reduced SO_2 and NO_X emissions in some sectors, but which has also been biased toward end-of-pipe emissions controls. This in turn has permitted older and inefficient power plants to continue to operate, thereby *increasing* GHG emissions.

Professionals new to the process of developing air quality plans, such as those in China and also many in parts of the western United States (where revised ambient air quality standards will be issued in 2011) will face a temptation to adopt planning structures that are already being used by other agencies with mature experience. We have argued here that a different framework, one that incorporates policy measures that improve local air quality and that reduce toxic and GHG pollutants, is preferable to the single pollutant approach—that by collaborating with energy agency colleagues and evaluating economic and public health benefits, a climate-friendly approach can achieve the same goals as traditional air quality planning at a lower long-run total cost, while simultaneously achieving energy and economic objectives, such as improved reliability, affordable electricity, economic development, and job creation.

Finally, we must emphasize that the choice is not traditional air quality management on the one hand and climate-friendly planning on the other. Climate-friendly air planning includes traditional measures such as SCR for NO_X emissions reductions on power plants. Rather than relying exclusively on end-of-pipe approaches to meet environmental goals, however, compliance options under a climate-friendly approach also include process changes, improved energy consumption by customers, and technologies such as CHP to improve the thermal efficiency of fuel used at industrial sites.

The fact that few pure climate-friendly air quality plans exist today is the driver for the compilation of best practices that have been assembled in this document. Budgetary concerns in many parts of the world are reason enough to transition to air quality plans that address local, toxic, and GHG emissions in an integrated fashion. Even where agency resources are not constrained, climate-friendly plans can improve economic competitiveness and energy security. Climate-friendly plans also improve agency effectiveness with the public and regulated sources by emphasizing policies that are part of a long-term strategy, that cover all pollutants, and that permit businesses to incorporate long-term air quality objectives into their investment decisions. To summarize, climate-friendly air quality principles include:

- Comprehensive planning and technical frameworks that assess the ability of policies to concurrently reduce emissions of multiple pollutants;
- Policies that can be adopted to also meet single-pollutant targets and public health goals;
- Long-term air quality planning that is coordinated with energy and economic regulation to ensure that the most cost-effective policies are implemented;
- The issuance of permits or licenses for new emissions sources based on best available technologies that represent the most efficient processes and uses of fuel at the enterprise and throughout the supply-chain; and
- The provision of long-term policy signals to existing emissions sources that enable pollution controls to be sequenced, and that adequate space is made to install the footprint for the best available emissions controls, even if the first modules installed are less than Best Available Control Technology (BACT.

As a lengthy document like this has a tendency to begin to be outdated as soon as it is finished, we hope to be able to develop a web-based version of this material that can continue to serve air quality agencies, researchers, and other parties by providing a means to update this work as new climate-friendly best practices are adopted globally. We would envision a structure in which people could submit policies and their benefits, and provide appropriate contacts, cites, and references to independently evaluate the veracity of the policies. We would especially welcome readers' thoughts and input on this concept, with suggestions to Chris James at cjames@raponline.org.