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CONTENTS

Meeting the Pollution Control Challenge in Central and Eastern Europe

Protecting environmental quality while pursuing economic development poses a particularly difficult challenge for Central and Eastern Europe, where political and economic systems are changing rapidly after decades of environmental neglect and economic mismanagement. This challenge also confronts advanced industrialized countries, which must make difficult decisions regarding priorities and procedures for providing assistance to the region. In cooperation with researchers at the World Bank, at the International Institute for Applied Systems Analysis, and in Central and Eastern European countries, scholars at Resources for the Future have been investigating some of the pollution problems the region faces and how these problems might be addressed. Highlighted in this issue of *Resources* are the results of some of these investigations, which were undertaken as part of the World Bank's Environmental Action Programme for Central and Eastern Europe.

The first two articles focus, respectively, on changes in the region's environmental conditions that are likely to result from economic restructuring and on the benefits of improvements in these conditions. The last three articles each deal with the design of effective environmental policies for economies in transition.

Several themes emerge in these investigations. One is that some air pollution problems in Central and Eastern Europe may not be as serious or as ubiquitous as once thought. A second theme is that, given their need to invest heavily in economic restructuring, Central and Eastern European countries must ensure that resources used in pollution control efforts will be directed to the efforts that garner the greatest benefits to society. A third theme is that, given their limited resources, Central and Eastern European countries must identify the most cost-effective mechanisms for dealing with their environmental problems.

Comparisons of incentive-based (IB) and command-and-control (CAC) environmental policies provide additional insights. The cost-saving potential of the IB policies may be limited, and the opportunity for using emission permit trading may hinge on the scope of the trading. But despite the difficulties in implementing them, IB environmental policies are worth pursuing in Central and Eastern Europe.

Melissa Edeburn

Motor Vehicles and Pollution in Central and Eastern Europe

Margaret A. Walls

Compared with motor vehicles in the United States, motor vehicles in Central and Eastern Europe are much more polluting, but they are also fewer in number and less used. As a result, both total and per capita motor vehicle emissions of carbon monoxide (CO), hydrocarbons (HCs), and nitrogen oxides (NO_x) are lower in Central and Eastern Europe than they are in the United States. Estimates of motor vehicle emissions levels in several Central and Eastern European countries in the near future indicate that these levels may not change substantially relative to population. The estimates, which are based on forecasts of the number of cars and the number of miles driven annually in the countries through the year 2010, suggest that per capita emissions of CO, HCs, and NO_x will remain below those in the United States even under a high emissions scenario. They imply that Central and Eastern European countries should avoid costly national regulation of motor vehicle emissions and instead focus on reducing driving in cities, where motor vehicle use poses the most severe air pollution problems, and decreasing the lead content of gasoline.

Air pollution problems in Central and Eastern Europe are well-documented. The problems receiving the most attention are those associated with the use of coal in power plants and heavy industry. Less understood are the air pollution problems that arise from the use of motor vehicles.

The primary pollutants emitted by motor vehicles that run on gasoline are carbon monoxide (CO), hydrocarbons (HCs), and nitrogen oxides (NO_x). Hydrocarbons and nitrogen oxides combine in the atmosphere to form ground-level ozone, the principal ingredient in urban smog. Motor vehicles that run on gasoline containing lead also emit lead into the atmosphere. Those that run on diesel fuel emit particulates and sulfur dioxide (SO_2).

The only accurate way to assess the extent of the pollution problems caused by the use of motor vehicles is to monitor ambient air quality. In the case of problems resulting from the use of leaded gasoline, it is also necessary to analyze the level of lead in the bloodstreams of individuals who are exposed to lead emissions. Unfortunately, in most Central and Eastern European countries there is no extensive testing of individuals' blood-lead levels, and there are few facilities that monitor ambient CO and ozone concentrations.

Given the lack of data on ambient air quality, an alternative way of assessing the extent of air pollution problems associated with motor vehicles in Central and Eastern Europe is to examine patterns of vehicle ownership, use, and emissions in the region. With Michael P. Walsh, an independent environmental consultant, I analyzed such patterns in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland in order to forecast future levels of emissions from motor vehicles in these countries. (At the time of the analysis, the Czech Republic and Slovakia were one country and therefore are referred to as one country throughout the findings reported below.) Our analysis focused on emissions of CO, HCs, NO_x, and lead rather than on particulates and SO_2, as motor vehicles account for less than 5 percent of total emissions of these two pollutants in most Central and Eastern European countries.

Patterns of vehicle ownership and use

Several statistics concerning car ownership and use seem to suggest that pollution problems stemming from motor vehicle use are less severe in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland than in the countries of the West. First, in these four countries the average number of cars per 1,000 people is 142—about 40 percent of the average ratio of cars to people in the western region of Europe and 25 percent of that in the United States. Second, cars in the four Central and Eastern European countries are driven less than cars in the West. On average, a car in one of these four countries is driven only half as many miles per year as a car in the United States.

Despite the fact that they are fewer in number and are driven fewer miles, cars in Central and Eastern Europe tend to be more polluting than cars in the West. This tendency is connected in part with the fact that cars in Central and Eastern Europe are much older than cars in the West. The average age of cars is 15 years in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland, but only 7.6 years in the United States. In addition, the percentage of very old cars being driven in these four countries is higher than that in the United States. In the Czech Republic and Slovakia, for example, 48 percent of the cars on the road are more than 10 years old, and in Hungary 42 percent are more than 10 years old. In the United States, however, only 30 percent are this old. Age can be an important factor in how much cars pollute because older cars generally lack the modern pollution control equipment, such as catalytic converters and electronic fuel injection, that newer cars have. In Central and Eastern

Europe this problem is compounded by the fact that the region's technology for producing vehicles with such equipment lags behind that of the West.

In addition to their comparatively old age, there are other reasons why cars in Central and Eastern Europe are some of the most polluting vehicles in the world. One is that they are poorly maintained. Another is that they are often defective when they come off the assembly line. Yet another is that they run on highly polluting fuels. The sulfur content of diesel fuel sold in Central and Eastern Europe is high, leading to high levels of particulate emissions. Perhaps more important, nearly all the gasoline sold in the region is leaded gasoline. Moreover, the lead content of that gasoline is typically higher than that of leaded gasoline in Western Europe. While the gasoline in most Western European countries contains 0.15 grams per liter (g/l) of lead, the lead content of gasoline averages between 0.3 g/l and 0.6 g/l in Poland, 0.3 g/l in Hungary, and 0.2 g/l in the Czech Republic and Slovakia.

Cars in Central and Eastern Europe make greater contributions to air pollution than cars in the West because they are relatively old and thus lack modern pollution control equipment, and because they run on highly polluting fuels.

Emissions from one segment of the vehicle population in Central and Eastern Europe are of particular concern. In most countries of the region, vehicles with 2-stroke engines are still being driven. These engines, which burn a mixture of gasoline and lubricating oil, emit a high level of hydrocarbons. Most Central and Eastern European countries have ceased production and banned imports of vehicles with 2-stroke engines; however, 9 percent of vehicles driven in Poland, 15 percent of vehicles driven in Bulgaria, and 40 percent of vehicles driven in Hungary have these engines.

Comparison of national motor vehicle emissions

One way to gauge the severity of air pollution problems caused by motor vehicles in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland is to compare motor vehicle emissions in these countries with those in the United States. To do this, we estimated total annual emissions of CO, HCs, NO_X, and lead from motor vehicles in each of the four Central and Eastern European countries in 1990 and in the United States in 1989 and in 1970, when motor vehicle emissions in that country were substantially uncontrolled. In order to account for the differences in the size of each of these countries, we made comparisons of the emissions on the basis of each country's total population.

It is widely held that the United States had unacceptably high ambient CO concentrations in 1970. Until approximately 1980, the national ambient CO standard of 9 parts per million was exceeded in many locations. Although ambient CO concentrations remain unacceptably high during the winter months in some high-altitude cities, the national average CO concentration today is well below the standard. A comparison of per capita CO emissions from motor vehicles in the United States in 1989—132 metric tons per 1,000 people—with those in the four Central and Eastern European countries in 1990—62 metric tons per 1,000 people—suggests that the latter countries have a less severe CO emissions problem than the United States has even today. Since CO emissions from motor vehicles do not pose much of a problem in the United States, it is possible that they do not pose much of a problem in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland.

Like CO emissions, lead emissions from motor vehicles were a serious problem in the United States in 1970. Since the country's phaseout of leaded gasoline, such emissions have become virtually a concern of the past. A comparison of per capita lead emissions from motor vehicles in the United States and in the four Central and Eastern European countries suggests that the latter countries have a less severe lead emissions problem than the United States did in 1970, but a more severe problem than the United States did in 1989. In the United States, emissions of lead per 1,000 people dropped from .761 metric tons in 1970 to .008 metric tons in 1989. In the four Central and Eastern European countries, emissions of lead per 1,000 people totalled .045 metric tons. Given their use of leaded gasoline, these countries may have a significant lead problem; however, it is difficult to determine how severe the problem is because data on the blood-lead levels of their city-dwelling citizens are limited.

Compared with CO and lead, ozone has posed a more difficult problem for the United States. Many urban areas continue to violate the U.S. ozone standard. Average ambient ozone concentrations have declined since the early 1970s, but not nearly as much as average ambient CO concentrations have. Emissions of hydrocarbons and nitrogen oxides, the two precursors of ozone, dropped from 46 metric tons and 31 metric tons per 1,000 people in 1970 to 44 metric tons and 24 metric tons per 1,000 people, respectively. While per capita HC and NO_X emissions from motor vehicles in the four Central and Eastern European countries—10 metric tons and 6.5 metric tons per 1,000 people, respectively—are less than those in the United States, it is impossible to conclude from this fact that the former countries do not have an ozone problem.

Comparison of car emissions in cities

One major drawback to the above comparisons of per capita motor vehicle emissions is that, because they are made on a nationwide basis, they do not reflect the fact that air quality problems—particularly those associated with motor vehicles—are inherently problems of urban areas. Therefore we estimated emissions on a city-by-city basis. In doing so, we compared total amounts of HC and CO emissions from cars (rather than emissions from all motor vehicles, as in the above comparisons) in three Central and Eastern European cities—Prague, Sofia, and Budapest—with those in one U.S. city—Milwaukee, Wisconsin.

Because car emissions figures for Central and Eastern European cities are not available, we had to estimate them for Prague, Sofia, and Budapest. We did so on the basis of a calculation involving the number of cars in each of the cities, the number of miles traveled annually per car in each of the countries of which the cities are capitals, and an estimate of the grams-per-mile emissions of U.S. cars prior to 1970. We performed the same calculation to estimate car emissions in Milwaukee, but in place of the estimate of the grams-per-mile emissions of U.S. cars prior to 1970 we used an estimate of the average grams-per-mile emissions of the U.S. car fleet in 1990. We obtained the latter estimate by running the U.S. Environmental Protection Agency's MOBILE 5.0 emissions model.

We chose to compare the car emissions in Milwaukee with those in the three Central and Eastern European cities for several reasons. First, the population of Milwaukee is almost the same as that of Prague and Sofia. Second, the summer temperatures in Milwaukee are very similar to those in Sofia and Budapest. This similarity is important because temperature is a strong predictor of evaporative HC emissions and ambient ozone concentrations. Third, Milwaukee has violated the U.S. ozone standard in recent years. Thus if our HC emissions estimates for Sofia, Prague, and Budapest are equal to or greater than those of Milwaukee, we venture that the former cities might have ozone problems.

In Prague, Sofia, and Budapest, total car emissions of hydrocarbons, an ozone precursor, are as high as or higher than those in Milwaukee, which violates the U.S. ambient ozone standard.

According to these estimates, total HC emissions from cars in Budapest are about 30 percent greater than HC emissions from cars in Milwaukee; HC emissions from cars in Prague are about 5 percent greater than those in Milwaukee; and HC emissions from cars in Sofia are about 10 percent less than those in Milwaukee. Thus Prague and Sofia have approximately the same amount of total HC emissions from cars as Milwaukee, and Budapest has a significantly greater amount than Milwaukee, even though the number of cars and the number of miles traveled per car are both much greater in Milwaukee than in the other three cities. There are approximately twice as many cars per 1,000 people in Milwaukee as there are in the three Central and Eastern European cities (560 compared with 340 in Prague, 269 in Sofia, and 250 in Budapest), and cars are driven about twice as many miles per year in Milwaukee as they are in the other three cities.

Since Milwaukee exceeds the U.S. ambient ozone standard, the above estimates suggest that Prague, Sofia, and Budapest may exceed that standard as well. The likelihood that Sofia and Budapest exceed the standard is increased by the fact that they have summer temperatures similar to those of Milwaukee. The likelihood that Prague exceeds the standard is increased by the fact that it has a lower percentage of total HC emissions attributable to motor vehicles than does Milwaukee: 33 percent compared with 42 percent. (Percentages of total HC emissions attributable to motor vehicles in Sofia and in Budapest are unavailable.) This means that Prague must have a greater amount of total HC emissions than Milwaukee and thus is likely to have an ozone problem.

It is more difficult to determine whether the three Central and Eastern European cities have a CO problem. Each has substantially more CO emissions from cars than Milwaukee; but since Milwaukee does not violate the U.S. ambient CO standard, it is difficult to draw any conclusions about the severity of ambient CO conditions in Prague, Sofia, or Budapest.

Forecasts of increases in motor vehicle ownership and use

One of the most important questions for policymakers in Central and Eastern European countries is whether they will have a motor vehicle pollution problem to deal with in the future. Will ownership and use of motor vehicles increase, and, if so, by how much? How will such an increase affect total emissions of HC, CO, NO_x, and lead? Should controls on motor vehicle emissions be required, and, if so, how stringent should they be?

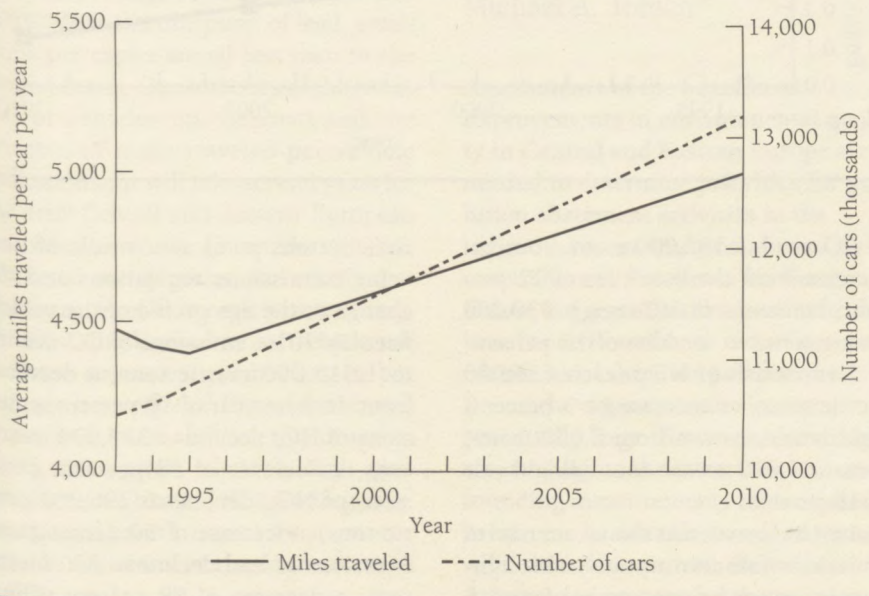
As a starting point in our attempt to answer these questions, we forecasted increases in the number of cars on the road and the number of miles traveled annually per car in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland through the year 2010. Using data from developed western countries, we established relationships among gasoline prices, gross national product (GNP), and car ownership and use. In

doing so, we implicitly assumed that these relationships will hold in the future for Central and Eastern European countries. We then used World Bank GNP forecasts for the four Central and Eastern European countries in question and our best estimates of future gasoline prices to forecast the number of cars on the road and the number of miles traveled annually per car through the year 2010. We then assumed that percentage increases in the number of trucks and motorcycles on the road and percentage increases in the number of miles traveled annually per truck and per motorcycle were the same as those for cars.

With respect to GNP, the World Bank predicts that it will drop or remain constant in the four countries during the early part of the forecast period (when the countries are continuing to undergo economic reconstruction), but that it will eventually rise by between 5 percent and 6 percent per year in each of the countries. With respect to retail gasoline prices, we expect that they will reflect world market oil prices, which we assume will gradually rise to $30 per barrel by the year 2010. By 1995, we expect that gasoline prices in the Czech Republic and Slovakia, Hungary, and Poland will also reflect tax rates similar to those in Western Europe. We anticipate that retail gasoline prices in Bulgaria will be somewhat lower than in the other three countries.

According to our forecasts of car ownership and car use, both the number of cars and the average annual number of miles traveled per car will increase over the forecast period (see figure, p. 5), but not by a large amount. By the year 2010, there will be more than 13 million cars in the four Central and Eastern European countries—an average of 167 cars per 1,000 people—and each car will be driven an average of slightly more than 5,000 miles per year. The number of cars and the number of miles driven will both be far lower in these countries than they were in the United States and Western European countries in the late 1980s. In fact, because of the decrease in GNP and the increase in gasoline prices in the early part of the forecast period, these numbers will actually fall initially.

Forecasts of the number of cars and the number of miles traveled per car in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland



High and low emissions scenarios

To determine how increases in motor vehicle ownership and use will affect levels of motor vehicle emissions of CO, HCs, NO_x, and lead in the four Central and Eastern European countries through 2010, we combined our forecasts of these increases with emissions-per-mile estimates obtained by running the MOBILE 5.0 emissions model under two scenarios. In our so-called high emissions scenario, we assumed that the types of vehicles and fuel used throughout the forecast period are similar to those used in 1993. In particular, we assumed that there are some minor controls for HC, CO, and NO_x emissions and that no new vehicles with 2-stroke engines are sold, but that no emissions standards are enforced. We also assumed that no effective vehicle inspection and maintenance programs are in place; that all gasoline is leaded; and that vehicles in the four Central and Eastern European countries are older, on average, than vehicles in the West.

In our so-called low emissions scenario, we assumed that new vehicles sold in the Czech Republic and Slovakia, Hungary, and Poland meet European Community (EC) emissions standards by 1995 and that new vehicles sold in Bulgaria meet these standards by the year 2000. For light-duty vehicles, the EC carbon monoxide emission standard is 4.35 g/mi; the combined hydrocarbon and nitrogen oxide emission standard is 1.55 g/mi. These standards are not as strict as current U.S. standards for vehicle emissions; however, most analysts agree that, in order to meet the EC standards, cars will have to be equipped with catalytic converters. Additional assumptions in the low emissions scenario are that effective vehicle inspection and maintenance programs are put in place; that unleaded gasoline's share of the total gasoline market gradually rises to 80 percent in the Czech Republic and Slovakia, Hungary, and Poland, and to 50 percent in Bulgaria by 2010; that all

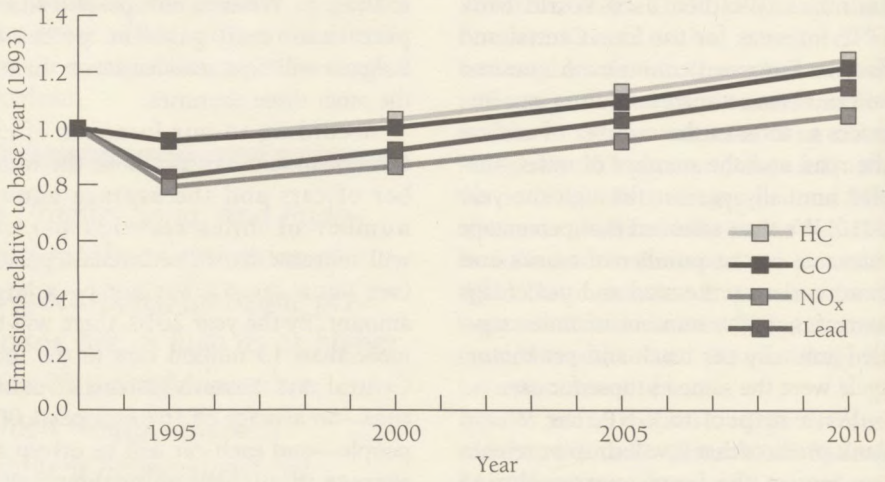
remaining leaded gasoline has a lead content of 0.15 g/l by the year 2000; and that percentages of younger and older cars in all four countries are similar to those in the United States.

We should note that the most likely emissions scenario might well be one that is intermediate between our high emissions scenario and our low emissions scenario. The high emissions scenario may be pessimistic in that some of the countries in question are already tightening vehicle emissions regulations. For example, all new cars sold in the Czech Republic and Slovakia after October 31, 1993 must be equipped with catalytic converters. Beginning in 1994, all new cars sold in Hungary must meet EC emissions standards. In recent years, the Czech Republic and Slovakia, Hungary, and Poland have all established import policies that favor the importation of new model vehicles and vehicles equipped with catalytic converters. Each of these countries has also set up vehicle inspection and maintenance programs. On the other hand, given the costs entailed by some of the new vehicle emissions control requirements and the poor economic conditions in these countries, enforcement of the requirements might be somewhat lax. For this reason, our low emissions scenario might be overly optimistic. However, both our scenarios should reasonably bound the true level of future emissions, given our forecasts of vehicle miles traveled.

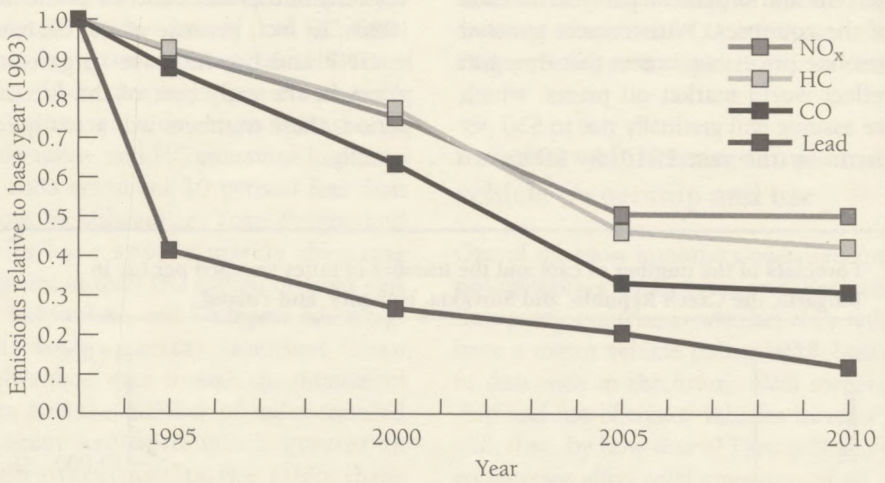
In our forecasts of motor vehicle emissions levels through the year 2010 in each of the four Central and Eastern European countries, emissions are indexed with 1990 (the base year), and emissions in that year are set equal to one. In the high emissions scenario, emissions of each pollutant fall or remain constant until 1995, then gradually rise throughout the remainder of the forecast period (see figure, top p. 6) as the annual number of vehicle miles traveled rises. By 2010, total emissions of CO, HC, and NO_x have risen in all four countries. Emissions of CO reach 5,182,000 metric tons, an increase from the base year of 22 percent; emissions of HCs reach 930,000 metric tons, an increase of 25 percent; and emissions of NO_x reach 616,000 metric tons, an increase of 5 percent. Lead emissions rise from 2,650 metric tons to 3,040 metric tons, an increase of 15 percent.

In the low emissions scenario, emissions fall continuously throughout the entire forecast period (see figure, bottom p. 6) as a result of new vehicle emissions regulations and the change in the age profile of the vehicle fleet. By 2010, emissions of CO decline to 1,315,000 metric tons, a decrease from the base year of 70 percent; emissions of HCs decline to 317,000 metric tons, a decrease of 58 percent; emissions of NO_x decline to 296,000 metric tons, a decrease of 50 percent; and emissions of lead decline to 320 metric tons, a decrease of 88 percent. These

Forecasts of total motor vehicle emissions in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland under a high emissions scenario.



Forecasts of total motor vehicle emissions in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland under a low emissions scenario.



figures suggest that that the decreases in emissions per mile that result from the enforcement of EC emissions standards for vehicles, the introduction of strict vehicle inspection and maintenance programs, the decline in the average age of vehicles, and the decrease in the lead content of gasoline far outweigh the expected increase in the number of miles traveled annually.

According to United Nations estimates, some population growth is expected in the four countries—primarily in Poland—over the forecast period; however, it is less than the predicted growth in emissions under the high emissions scenario. Thus, in that scenario there is a slight increase in CO, HC, and NO_x emissions relative to population. By 2010, approximately 66 metric tons of CO, 12 metric tons of HC, 8 metric tons of NO_x, and 0.039 metric tons of lead are emitted per 1,000 people. With the exception of the figure for lead, these figures are higher than emissions figures for 1990, but they are still far lower than emissions figures relative to population in the United States.

Even under a worst case scenario, our forecasts do not indicate a large increase in total vehicle emissions in Bulgaria, the Czech Republic and Slovakia, Hungary, and Poland before 2010. With the exception of lead, emissions per capita are all less than in the United States. Our forecasts of the number of vehicles on the road and the number of miles traveled per vehicle indicate that it will take several years for the four Central and Eastern European countries to recover from reduced GNP, increased energy prices, and other negative impacts of economic restructuring. By 2010, the level of motor vehicle use in these countries will have risen but will not have equaled that of the United States and most of Western Europe in 1990. Even given relatively high g/mi emissions estimates, this finding suggests that future increases in motor vehicle emissions in the four countries will be small.

Policy implications

The above-noted findings suggest that gradually eliminating leaded gasoline and adopting some other policies to control motor vehicle emissions may be prudent. However, they also suggest that requiring vehicles to be equipped with catalytic converters and setting up vehicle inspection and maintenance programs in order to meet EC standards for emissions of CO, HC, and NO_x may be unwise in the short run. These costly measures may not be needed before 2010 if energy prices are allowed to rise to world market levels and the motor vehicle market is opened up so that relatively new and clean-running vehicles can be purchased in Central and Eastern Europe.

Given that they are severely limited in Central and Eastern European countries, resources might best be devoted to monitoring of ambient air quality and to the identification of cost-effective policies for reducing motor vehicle emissions in cities, where some significant air pollution problems might exist. Such policies could focus on the use of economic instruments that will reduce driving and improve traffic flows, and they could obviate the need to promulgate costly national regulation of motor vehicle emissions.

Margaret A. Walls is a fellow in the Energy and Natural Resources Division at Resources for the Future. A detailed account of the research on which this article is based can be found in discussion paper ENR93-22, "Motor Vehicles and Pollution in Central and Eastern Europe," by Margaret Walls.

Assessing the Health Benefits of Improved Air Quality in Central and Eastern Europe

Alan J. Krupnick, Kenneth W. Harrison, Eric J. Nickell, and Michael A. Toman

Assessments of the benefits of improvements in environmental quality in Central and Eastern Europe are needed to determine priorities for pollution abatement activities in the region. A recent study conducted by researchers at Resources for the Future suggests that the human health benefits attributable to reductions in emissions of three air pollutants in five of the region's countries are potentially large. However, the study also highlights the uncertainties surrounding measurements of decreases in adverse health effects and economic valuations of improved air quality. Attempts to account for these uncertainties yield findings that strengthen the researchers' assertion that air pollution control should be a target of environmental and economic policies in Central and Eastern Europe.

Central and Eastern European countries are simultaneously attempting to address environmental problems and rebuild their economies. Given that substantial financial investment will be needed to accomplish the latter goal, it is important that resources used to attain the former goal be spent on pollution abatement efforts that will garner the greatest benefits to society. Assessments of the benefits that

can be obtained through improved environmental quality help policymakers to set rational priorities for environmental cleanups. If such assessments indicate that the benefits are potentially large, they would highlight the importance of not ignoring the environment in pursuing economic restructuring.

It appears that reductions in air pollution in the five Central and Eastern European countries under consideration have the potential to yield health benefits equal to at least 1 percent to 3 percent of each country's gross domestic product and possibly equal to an even greater percentage of GDP.

We recently conducted a preliminary assessment of one category of benefits that can be obtained from improvements in environmental quality: the health benefits of reduced air pollution. Specifically, we examined the effects on human health of reductions in ambient concentrations of particulates, sulfur dioxide (SO_2), and lead in each of five countries—Bulgaria, the Czech Republic, Hungary, Poland, and Ukraine.

We consider the assessment to be preliminary because it has several limitations. One limitation is the small number of pollutants considered. Data availability largely dictated the scope of the assessment. For example, the lack of data on ground-level ozone, which is known to have adverse health effects, meant that the benefits of reducing this air pollutant could not be examined. Another limitation of the assessment is that only one kind of benefit from air quality improvement is analyzed. Scientific uncertainties and lack of data precluded a systematic assessment of benefits other than improved human health that are attained by reducing air pollution. In particular, these uncertainties made it impossible to assess reductions in ecological damages that could result from improvements in air quality. Yet another limitation is that no comparisons are made among the benefits of ameliorating different kinds of environmental hazards. For example, lack of data on the extent and nature of water contamination precluded a comparison of the benefits of improved water quality with those of improved air quality.

Despite these limitations, some important conclusions emerge from our analysis. It appears that reductions in air pollution do have the potential to yield substantial health benefits in Central and Eastern European countries—benefits that are at least 1 percent to 3 percent of gross domestic product (GDP) in these countries, and quite possibly equal to an even greater percentage of GDP. While we do not have the information on air pollution abatement costs that would be needed for a full-scale benefit-cost analysis, we believe the size of the potential benefits of reduced air pollution should make air pollution control an important target of environmental and economic policies in Central and Eastern Europe. Control of particulate emissions should be a particularly important target, given that this air pollutant contributes significantly to health damages and is often fairly cheap to abate.

Methodology of assessment

Our analysis focuses on the potential benefits of air quality improvements sufficient to meet current European Community (EC) standards for the three pollutants under consideration. Therefore, the first step in the analysis was to establish baseline ambient concentrations of particulates, SO_2, and lead in Bulgaria, the Czech Republic, Hungary, Poland, and Ukraine. From the World Bank and sources in the region we obtained data on ambient conditions in more than 200 cities and towns, as well as in subdivisions of some large cities (such as Budapest and Prague) within these countries. The percentages of total national population that are represented by data on particulates in our sample range from 17 percent (Poland) to 34 percent (Hungary and Ukraine). The percentages of total national population that are represented by SO_2 data in our sample generally range from 19 percent (Poland) to 34 percent (Ukraine) but rise as high as 72 percent (Hungary). Data on ambient lead concentrations were unavailable for the Czech Republic and Ukraine, and were available for only a few urban areas in Hungary and Poland. Therefore, the percentages of total national population that are represented by lead data in our sample range from less than 5 percent (Hungary and Poland) to 23 percent (Bulgaria).

All the data on ambient concentrations of the three pollutants date from the late 1980s, and thus do not reflect changes in these concentrations that have resulted from current economic downturns in the five Central and Eastern European countries. Because we do not possess detailed information about the dispersion of pollutants in specific locations, we assume that all people in a particular sample area have the same pollutant exposures—that is, they all live with the same ambient conditions as those measured at the pollution monitoring stations from which our data are derived.

After collecting ambient pollutant concentration data, we calculated the degree to which ambient concentrations of each pollutant would have to be reduced in each sample area in order to meet EC standards. EC standards for particulates and for SO_2 limit both average annual exposures and maximum daily exposures. Therefore we calculated reductions in average exposures sufficient to meet both limits (see table, p. 9). The percentage reductions we estimated are quite substantial. Those for particulates generally range from 40 percent to 49 percent, although in the Czech

Photo courtesy of Antonin Kratochvil/Dot Pictures

The adverse health effects of poor air quality range from asthma attacks and so-called restricted activity days to heart disease and premature mortality. The benefits of reducing these effects appear to be significant.

Republic the reduction needed to meet EC standards is only 5 percent. Percentage reductions needed to meet EC standards for SO_2 range from 12 percent in Hungary to 70 percent in Bulgaria. Those needed to meet EC standards for lead range from 23 percent in Bulgaria and Poland to 43 percent in Hungary.

The particulate reduction figure for the Czech Republic is puzzling, given the frequent references in both popular reports and scholarly studies to the poor air quality of northern Bohemia. The only explanation we can offer is that the sample areas in this country seem to have relatively little pollution.

Our next step was to estimate the reductions in adverse health-related effects that would result if ambient pollutant concentrations declined enough to meet EC standards. We calculated these reductions using a dose-response model that accounts for a variety of health effects, ranging from asthma attacks and so-called restricted activity days to heart disease and premature mortality. The model, which was prepared by researchers at Resources for the Future and elsewhere for a study of the social costs of energy in the United States, reflects a balancing of expert opinions distilled from the clinical and epidemiological literatures on the health effects of air pollution. Two assumptions of the model are noteworthy. The first assumption is that the relationships between doses (exposures) and responses (health effects) are largely linear—that is, the rates of health effects do not grow as exposures increase. The second assumption is that there are benefits from improving air quality even when ambient pollution concentrations are already low.

It should also be noted that the dose-response relationships assumed by the model are based on those documented in the United States and Western Europe. Thus they do not reflect differences in the basic health status of residents of Central and Eastern Europe. We suspect that our model underestimates the reduction in adverse health effects that would occur if pollution declined in the countries included in our analysis. This suspicion is based on the assumptions that individuals living in Central and Eastern Europe are not as healthy as individuals living in the West and that the less healthy an individual is, the more sensitive he or she will be to pollution exposures. Given all the uncertainties and sources of controversy surrounding dose-response relationships, our dose-response model does not attempt to calculate a single response for each health effect. Instead, it calculates a low, a middle, and a high response.

Once we calculated reductions in adverse health effects, we proceeded to calculate a per-unit economic value for the health improvements. Like the preceding step, this step is controversial on both philosophical and practical grounds. Some people are troubled by the notion of assigning monetary values to human health generally and especially to risks of premature mortality. While we recognize these concerns, we believe that it is possible—in principle—to obtain useful information about what trade-offs people are willing to make between health and other social goods.

Even if one accepts the principle of imputing monetary values to health, the practical problem of assessing willingness-to-pay (WTP) for reductions in exposure to health threats must be addressed. Our model for valuing such reductions includes estimates of both direct health damage costs—such as medical expenses and wage rates that reflect the value of workers' restricted activity days—and estimates of WTP for reduced exposure to health threats. The latter estimates are derived from contingent valuation studies in which individuals are asked to reveal their WTP for reduced exposure to health threats. Like our dose-response model, our valuation model attempts to reflect the preponderance of expert opinion in the literature concerning monetary valuations of health effects. To reflect the uncertainties in existing estimates of WTP, the model calculates low, middle, and high valuations.

Average Percentage Reductions in Total Suspended Particulates, Sulfur Dioxide, and Lead Needed to Meet European Community Standards for Ambient Concentrations of These Air Pollutants

Country	Total suspended particulates	Sulfur dioxide	Lead
Bulgaria	49	70	23
Czech Republic	5	26	not available
Hungary	40	12	43
Poland	47	42	23
Ukraine	49	32	not available

All of the WTP and medical cost valuations used in our analysis are derived from analyses of such valuations in the United States and Western Europe. Because we could not develop independent estimates of medical costs and WTP for reduced exposures to health risks for Central and Eastern European countries in the course of our analysis, we adjusted the valuations made in the West to a scale relevant to Central and Eastern Europe. We took two approaches in making this adjustment. The first approach was to scale all values by the ratio of average income in Central and Eastern Europe to average income in the United States—a ratio of about 0.08. This approach may understate valuations of health risks, and particularly valuations of reduced mortality risks, in Central and Eastern Europe. Some evidence suggests that mortality valuations in this region do not fall in strict proportion to declines in income; this evidence suggests that they fall less than declines in income. To account for this possibility, our second approach to adjusting valuations was to set the income elasticity for the mortality valuation at 0.35, rather than at an elasticity of 1.0—the elasticity assumed in the relative wage approach.

The final step in our analysis was to estimate aggregate health-benefit values for the countries under consideration. This involved multiplying together the estimated air quality improvement figures—which were derived from ambient particulate, SO_2, and lead concentrations reductions sufficient to meet EC standards—and the values of improved health conditions indicated by the dose-response and valuation models. This calculation provides measures of benefits to populations in the sample areas. To obtain benefit figures for the entire population of each country considered, we made assumptions about the pollution to which people not in our sample areas are exposed. We considered two different cases to account for our uncertainty about the pollution exposures of these people. In the first case, the assumption is that the areas not in the sample have air quality that meets EC standards, and thus there is no need to calculate any health benefits for them. This case represents a lower bound for the national benefit figures. In the second case, the assumption is that air quality in the areas outside the sample is equal to the average air quality in the sample areas of each country.

Direct health damage costs and willingness-to-pay (WTP) for reduced exposure to health risks may not be the same in Central and Eastern Europe as they are in the West; therefore estimates of such costs and WTP in the West must be adjusted to a scale relevant to Central and Eastern Europe.

We also considered a case in which all areas in each of the countries under consideration must make the same percentage reductions in ambient concentrations of particulates, SO_2, and lead, whether or not the sample data indicate that the areas meet EC standards for the concentrations. The percentage reductions we set for each country correspond to the average reductions in the sample areas when EC standards are met. Analysis of this case allowed us to calculate the additional health benefits that could be reaped from making air quality improvements beyond those that would be required to meet EC standards.

Results of analysis

Our estimates of the health benefits obtained by meeting EC standards for particulates, SO_2, and lead in Bulgaria, the Czech Republic, Hungary, Poland, and Ukraine indicate that these benefits are potentially large (see table, p. 11). These benefits are expressed as a percentage of a country's GDP in 1988. As noted above, we calculated low, middle, and high estimates for both reductions in health effects and valuations of these reductions under two different assumptions about how benefits in the sample areas are scaled to the national level. An examination of the middle-range estimates indicates that the health benefits of meeting the EC standards generally range from 1 percent to 3 percent of GDP, even if we assume that areas not in the sample already meet EC air pollution standards. The notable exception is that no such benefits are attained by meeting EC standards in the sample areas in the Czech Republic. This finding reflects the fact that in these areas only an average 5 percent reduction in particulate emissions is needed to meet the EC standard for ambient concentrations of particulates.

If we assume that the air quality of the areas not included in the sample is the same as the average air quality of areas in the sample, the national benefit range would shift to about 4 percent to 12 percent of GDP, given middle-range estimates of health effects and valuations. Low estimates of health effects and valuations shift this benefit range downward, but not as much as high estimates shift it upwards. With low estimates, the national benefit range is about 1 percent to 4 percent of GDP; with high estimates, it is 14 percent to 34 percent of GDP.

Almost all of the estimated benefits are attributable to reductions in ambient concentrations of particulates. Two factors may account for this finding. One is that our data on the percentage of a country's population that is exposed to lead are not as comprehensive as our data on the percentage of a country's population that is exposed to particulates and SO_2. If we had lead exposure data for Ukraine and the Czech Republic, and more such data for the other three countries under consideration, we expect the benefits of reducing ambient lead concentrations would increase.

Estimates of the Economic Benefits Obtained by Meeting European Community Standards for Ambient Concentrations of Total Suspended Particulates, Sulfur Dioxide, and Lead (Expressed as a Percentage of a Country's GDP in 1988)

Country	Estimates for sample population	Extrapolation to national population[1]
Bulgaria	2.6	10.1
Czech Republic	0.0	0.0
Hungary	2.3	11.5
Poland	0.9	5.5
Ukraine	1.4	4.1

Note: Figures reflect middle-range estimates of reductions in health effects and economic valuations of these reductions. Economic valuations reflect valuations made in the West and adjusted to a scale relevant to Central and Eastern Europe on the basis of the difference between the average income in the United States and that in Central and Eastern Europe.

[1] In extrapolating the health benefits enjoyed by a sample population to those enjoyed by a national population, it is assumed that average air quality outside the sample areas within a country is the same as the average air quality inside the sample areas.

Another factor that may account for our finding that the majority of estimated benefits are attributable to reductions in ambient concentrations of particulates is the fact that our dose-response model assigns greater health effects to particulates than to SO_2. Most of the medical literature suggests that particulates are much more harmful to human health than airborne SO_2, which primarily affects materials and ecosystems. However, a portion of SO_2 in the atmosphere converts to sulfate aerosols (SO_4), which are known to be a health hazard but which are measured in the particulate data. Thus our estimates of benefits resulting from the reduction of ambient concentrations of total suspended particulates include benefits ultimately attributable to the reduction of ambient concentrations of SO_2 emissions. It is not possible on the basis of currently available information to determine how much of measured particulates is sulfate aerosols.

Our sensitivity analysis of the valuation of premature mortality risk indicates that assumptions about this valuation significantly affect the outcomes of the valuation. For example, when an income elasticity of 0.35 is used to scale the value of reduced mortality risk in Central and Eastern Europe, middle-range estimates of total health benefits rise to a level comparable to that when calculations are based on high estimates of health effects and valuations of reduced health risks. The outcomes of assuming uniform pollution reductions are more mixed. When uniform reductions in ambient concentrations are required across the sample areas, some of which already meet EC air pollution standards, the resulting benefits are greatest in Poland. This country has the largest share of sample locations that meet EC standards, yet it still stands to gain health benefits from additional reductions in air pollution.

Research needs

Our findings support the assertion that air pollution control should be a target of economic and environmental policies in Central and Eastern Europe. Clean air is not a luxury that only rich countries can afford to pursue. Our findings also underscore the importance of controlling particulates—one of the most socially beneficial pollution abatement options.

However, our analysis highlights the large uncertainties we face in putting an economic value on improved air quality. Some of this uncertainty is due to gaps in the basic knowledge of medical science—gaps that might not lessen substantially in the short term. Nevertheless, there are activities that could considerably reduce our uncertainties about valuations of air quality improvement in Central and Eastern Europe. One such activity is to conduct research that will augment knowledge about air quality in the region and the effects of air quality on human health and the environment. Such research will require intensive data collection efforts and cooperative air chemistry, environmental monitoring, and medical science research by experts in Central and Eastern Europe and in the West.

An equally important activity is the effort to better understand the values that residents of Central and Eastern Europe actually place on improved air quality. Here again, collection of relevant information about direct damage costs and measurement of willingness-to-pay for improved air quality offers a significant opportunity for cooperation between experts in Central and Eastern Europe and those in the West. Although they will be neither easy nor cheap, such efforts could set the stage for a wide assessment of pollution damages and priorities. Given the continuing economic and environmental difficulties facing Central and Eastern Europe, these efforts are an important component in determining responsible environmental policies in the region.

Alan J. Krupnick is a senior fellow and Kenneth W. Harrison is a research assistant in the Quality of the Environment Division at Resources for the Future (RFF). Michael A. Toman is a senior fellow and Eric J. Nickell is a research assistant in the Energy and Natural Resources Division at RFF. *A more detailed account of the issues addressed in this article can be found in discussion paper ENR93-19, "The Benefits of Ambient Air Quality Improvements in Central and Eastern Europe: A Preliminary Assessment," by Krupnick, Harrison, Nickell, and Toman.*

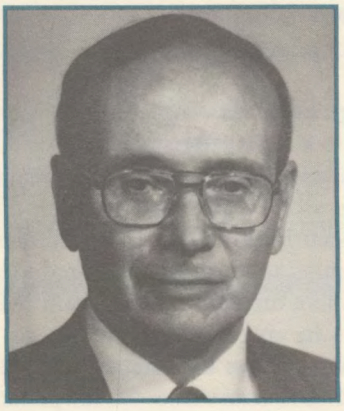
INSIDE RFF NEWS AND PUBLICATIONS

New directors

Mäler, Press, Solow join RFF directors

Three new members were elected to RFF's board of directors at the board meeting held in Washington, D.C., on October 7 and 8, 1993. They are economist **Karl-Göran Mäler,** director of the Beijer Institute on Ecological Economics at the Royal Academy of Sciences in Stockholm, Sweden; geophysicist **Frank D. Press,** senior fellow in the Department of Terrestrial Magnetism at the Carnegie Institution of Washington; and economist **Robert M. Solow,** Institute Professor of Economics at the Massachusetts Institute of Technology.

Karl-Göran Mäler earned his Ph.D. equivalent from the University of Stockholm following study at Stanford and MIT as well as at Stockholm. He has been a member of the Royal Academy of Sciences since 1981, during which time he has also served on the Prize Committee for the Bank of Sweden Prize in Economic Science (in memory of Alfred Nobel). He is a past member of the Swedish Council of Advisers and past president of the Swedish Economic Association. During the summer of 1973 at RFF, Mäler presented several seminars, including one on environmental problems of the Baltic that helped to develop a new direction in RFF's environmental studies. His 1974 RFF publication *Environmental Economics: A Theoretical Inquiry* addressed the statics and dynamics of a new theory regarding resource allocation that was devised at RFF and applied the theory to problems of environmental analysis.



Frank Press holds doctoral and master's degrees from Columbia University and an undergraduate degree from City College of New York. He served as science adviser to the President of the United States and director of the Office of Science and Technology Policy from 1977 to 1980, and was president of the National Academy of Sciences from 1981 to 1993. Press was a member of the faculty of the Department of Earth and Planetary Sciences at MIT from 1965 to 1977. He was named by *U.S. News and World Report* to be the most influential scientist in America in 1982, 1984, and 1985. He is a member of numerous professional societies, including the American Geophysical Union, where he served as president in 1973, and the French Academy of Sciences, the Royal Society (UK), and the Academy of Sciences of the former USSR.

Robert Solow holds bachelor's, master's, and doctoral degrees from Harvard University. He joined the MIT faculty in 1949, and has been professor of economics there since 1958. Solow was awarded the Nobel Prize in Economic Science in 1987. His other awards include the John Bates Clark Medal of the American Economic Association (1961) and Harvard University's Wells Prize (1951), as well as nineteen honorary degrees from universities in six different countries. A member of many learned societies, Solow has served as president of the American Economic Association and the Econometric Society and vice president of the American Association for the Advancement of Science. He is a trustee of the Woods Hole Oceanographic Institution and the Center for Advanced Study of Behavioral Sciences (where he has served as chairman since 1987). Solow helped commemorate RFF's fortieth anniversary in October 1992 by delivering a lecture entitled "An Almost Practical Step Toward Sustainability" to the RFF board of directors and invited guests from the natural resource and environmental policy community.

Mäler and Press will commence their service on RFF's board in April 1994; Solow will begin his term in October 1994.

Appointments and awards

RFF president **Robert W. Fri** was recently named chair of the National Research Council's Committee on the Technical Basis for the Health and Safety Standard at Yucca Mountain, the proposed Nevada site for a high-level nuclear waste repository. Two members of RFF's extended family, Gilbert White and John Ahearne, also serve on the committee.

Katherine N. Probst, a fellow in RFF's Center for Risk Management, was appointed by EPA administrator Carol Browner to serve on the Superfund Committee under the auspices of the National Advisory Council for Environmental Policy and Technology. The purpose of the committee is to provide EPA with an objective overview of the issues and opportunities for change in the Superfund program.

The Rockefeller Foundation has awarded a Residency to **Pierre R. Crosson** to spend a month next spring at the foundation's facility in Bellagio, Italy. Crosson, senior fellow in RFF's Energy and Natural Resources Division, will use the time to continue to work on incorporation of natural resource and environmental issues in the agendas of agricultural research institutions in the developing countries.

Marion Clawson, senior fellow emeritus in RFF's Energy and Natural Resources Division, has been named the 1993 recipient of the Sustained Achievement Award presented by the Renewable Natural Resources Foundation.

Center for Risk Management director **Terry Davies** was elected chairman of the board of RESOLVE, Inc., a nonprofit organization engaged in environmental dispute resolution and regulatory negotiation that was formerly the dispute resolution program of the World Wildlife Fund.

RFF vice president **Paul R. Portney** and former senior fellow **A. Myrick Freeman III** have been appointed co-chairmen of the Environmental Economics Advisory Committee of EPA's Science Advisory Board by Administrator Carol Browner.

New books

The Measurement of Environmental and Resource Values: Theory and Methods

by A. Myrick Freeman III

Estimates of the economic values of environmental and resource services can be a valuable part of the information base supporting resource and environmental management decisions. This premise is substantiated by a number of current environmental and resource policy issues, all of which involve in one way or another questions of economic values and trade-offs. For example, the achievement of the air and water pollution control objectives established by Congress is requiring massive expenditures on the part of both the public and private sectors, but is this diversion of resources from the production of other goods and services making us better off? By providing measures of the economic values of the services of environmental and natural resource systems, the discipline of economics can contribute to answering questions such as this.

The present publication reviews and summarizes the basic theory of economic welfare measurement and derives resource evaluation and benefit measurement techniques that are consistent with this underlying theory. It provides an overview of valuation and welfare measurement methods and discusses the relationship between the economic methods of valuation and the physical and biological relationships that define the resource and environmental systems being valued. In several chapters that constitute its theoretical core, the book lays out the basic premises and value judgments that underlie the economic concept of benefits and presents the basic theory of the measurement of economic welfare changes, as well as introduces the basic methods and models for deriving welfare and value measures from the revealed choices of individuals and from observed changes in market prices. Subsequent chapters discuss the concept of nonuse or existence value and show that indirect methods of measurement are not likely to be capable of measuring this type of value; describe methods for obtaining hypothetical data, rather than observed prices and quantities, for calculating welfare measures; take up the question of valuation across time and the role of discounting in welfare measurement; and extend the theory of value and welfare change to a situation of risk where people are uncertain about what the actual state of the world will be. The remaining chapters describe the application of the various methods and models for welfare measurement to specific situations such as measuring the values of environmental changes affecting producers' costs and productivity, environmentally induced changes in longevity and health, applications of the hedonic price model to housing prices and wage rates, and the valuation of resources that support recreation activities.

November 1993. 516 pages.
$65.00 cloth. ISBN 0-915707-68-3.
$24.95 paper. ISBN 0-915707-69-1.

Assessing Surprises and Nonlinearities in Greenhouse Warming: Proceedings of an Interdisciplinary Workshop

edited by Joel Darmstadter and Michael A. Toman

Although society has a great interest in the risks posed by global climate

change, this interest is not matched by available knowledge. In debates about the magnitudes and consequences of human-induced climate change, emphasis is placed on what could occur as humankind loads the atmosphere with greenhouse gases. Effects that are unexpected are of particular concern, as is the question of nonlinearities—responses of natural or socioeconomic systems that are disproportionate to changes in stimuli and that may threaten the adaptive capacities of the systems in question. Nonlinear and unexpected impacts complicate the problem of valuing effects that span generations and involve large spatial scales with substantial nonmarket assets as well as market goods.

In March 1992, Resources for the Future held a conference to examine these issues from both natural science and economic perspectives. Revised versions of papers commissioned for the conference, along with an added paper and an introduction and overview, constitute the present publication.

Of the six collected papers, three are devoted to natural science dimensions of the greenhouse problem. In them, contributors survey the state of knowledge concerning climate change, address nonlinearities and surprises in the impact of climate and weather on agriculture, and review a number of implications of greenhouse warming for a variety of largely unmanaged ecosystems. Each of the three ensuing papers addresses uncertainty about the potential damages to human and natural systems from the perspective of economic analysis. The first of these focuses on the implications of uncertainty about the damage function, while the other two revolve around the desirability of moving beyond one of the few efforts to estimate what magnitude of greenhouse gas abatement may be economically justified by the prospective dollar measure of damages avoided.

October 1993. 158 pages. $25.00 paper. ISBN 0-915707-71-3.

Making National Energy Policy

edited by Hans H. Landsberg

Market forces determine much of energy's use, as well as associated costs and benefits. But energy also generates problems that are beyond the capacity of the market to resolve satisfactorily. Environmental pollution is perhaps the most intricate and intractable among them. Supply assurance in the context of national security is another, and so is the concern for equity.

The present volume presents five lectures addressing areas of substantial importance to the making of U.S. energy policy, which attempts to give direction to the production, use, transportation, and distribution of energy to help achieve the array of societal goals in the most compatible ways. The first lecture provides a comprehensive view of current national energy policy issues: what forces underlie the policy discussions, some possible rationales for why policy initiatives have been frustrated, and some thoughts on goals or components of an appropriate strategic framework for implementing policy. The second lecture addresses the question of whether free-market pricing and allocation of energy are in the best interest of energy security, or whether government intervention in private markets is required to protect that interest. The third lecture offers a nonconventional view of the relationship between energy and environmental issues. Its argument is that environmental policy does not exert a major effect on energy markets. The fourth lecture analyzes the choice of governmental jurisdiction for energy security and environmental policies. The final lecture considers whether electric power, a "natural monopoly," can be regulated. An exercise in institutional/technological inventiveness and speculation, it is highly topical, given the development in this country of a serious debate about restructuring the electric power industry.

The lectures were first written for the John M. Olin Distinguished Lectureship Series in Mineral Economics at the Colorado School of Mines during the 1991-92 academic year, and subsequently revised in light of comments and recent developments.

September 1993. 150 pages. $22.50 paper. ISBN 0-915707-70-5.

Seminar

Seminar seeks the price of a human life

"When Is a Life Too Costly to Save—Evidence from Environmental Regulations" was the topic of a Resources for the Future Seminar presented on October 20 by Maureen L. Cropper, RFF senior fellow serving a one-year appointment as principal economist at the World Bank, and George L. Van Houtven, assistant professor of economics at East Carolina University. Cropper and Van Houtven utilized a comprehensive database they assembled to analyze the Environmental Protection Agency's regulations pertaining to three classes of pollutants—pesticides, asbestos, and hazardous air pollutants. Their purpose was to determine which factors appeared to influence the standards established by EPA regulators for the three types of pollutants. In addition, their analysis enabled Cropper and Van Houtven to determine the value of a statistical life implicit in these regulations.

A full-length article based upon the seminar will appear in the next issue of *Resources*.

Discussion papers

RFF discussion papers convey the preliminary findings of research projects for the purpose of critical comment and evaluation. Unedited and unreviewed, they are available at a cost of $3.00 each to interested members of the research and policy communities. Price includes postage and handling. Prepayment is required.

The following papers have recently been released.

Center for Risk Management

- "Desirable Attributes of Environmental Regulations," by Fred D. Hoerger. (CRM93-01)

- "When Is a Life Too Costly to Save? The Evidence from Environmental Regulations," by George L. Van Houtven and Maureen L. Cropper. (CRM93-02)

- "Toward Less Overconfident Comparisons of Uncertain Risks: The Case of Aflatoxin and Alar," by Adam M. Finkel. (CRM93-03)

- "Do Benefits and Costs Matter in Environmental Regulation? An Analysis of EPA Descisions under Superfund," by Shreekant Gupta, George L. Van Houten, and Maureen L. Cropper. (CRM93-04)

Energy and Natural Resources Division

- "Alternative Standards and Instruments for Air Pollution Control in Poland," by Michael A. Toman, Janusz Cofala, and Robin Bates. (ENR93-16)

- "Compensation Principles for the Idaho Drawdown Plan," by Dallas Burtraw and Kenneth D. Frederick. (ENR93-17)

- "Estimating the Effects of Climate Change and Carbon Dioxide on Water Supplies in the Missouri River Basin," by Kenneth D. Frederick, Mary S. McKenney, Norman J. Rosenberg, and Daniel K. Balzer. (ENR93-18)

- "The Benefits of Ambient Air Quality Improvements in Central and Eastern Europe: A Preliminary Assessment," by Alan J. Krupnick, Kenneth W. Harrison, Eric J. Nickell, and Michael A. Toman. (ENR93-19)

- "Two Essays on Water Quality in Central and Eastern Europe: Policies for Water Quality Management in Central and Eastern Europe," by Charles M. Paulsen, and "A Description of Water Quality in Hungary," by Hajna Fejerdy-Dobolyi. (ENR93-20)

- "Toward a Theory for Transitional Economies," by Andrew B. Miller. (ENR93-21)

- "Motor Vehicles and Pollution in Central and Eastern Europe," by Margaret A. Walls. (ENR93-22)

Quality of the Environment Division

- "Transaction Costs and the Performance of Markets for Pollution Control," by Robert N. Stavins. (QE93-16)

- "Can Markets Value Air Quality? A Meta Analysis of Hedonic Property Value Models," by V. Kerry Smith and J. C. Huang. (QE93-17)

- "Determinants of Participation in Accelerated Vehicle Retirement Programs," by Anna Alberini, Winston Harrington, and Virginia McConnell. (QE93-18)

- "Bridging the Gap between State and Federal Social Costing," by Dallas Burtraw and Alan J. Krupnick. (QE93-19)

- "Cross-Country Analyses Don't Estimate Health-Health Responses," by V. Kerry Smith, Donald J. Epp, and Kurt A. Schwabe. (QE93-20)

- "Cost-Effective Water Quality Monitoring Strategies in Central and Eastern Europe," by Charles M. Paulsen and László Somlyódy. (QE93-21)

- "The Promise and Prospect for SO_2 Emission Trading in Europe," by Dallas Burtraw. (QE93-22)

- "The Energy Paradox and the Diffusion of Conservation Technology," by A.B. Jaffe and Robert N. Stavins. (QE93-23)

- "Cost-Effectiveness of Remote Sensing of Motor Vehicle Emissions," by Winston Harrington and Virginia D. McConnell. (QE93-24)

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RFF researchers tour Superfund site

As part of their ongoing investigation of various issues related to the Superfund program, researchers at Resources for the Future (RFF) visited one of the sites on the National Priorities List (NPL) compiled by the U.S. Environmental Protection Agency (EPA). On July 8, Eugene Dennis of EPA Region 3 led the researchers on a tour of Tysons Dump in Upper Merion Township in Pennsylvania. During the tour, Dennis and employees of Ciba-Geigy (the company responsible for overseeing the site cleanup) described efforts to mitigate health and environmental risks posed by groundwater and soils on the four-acre site, which is contaminated with chlorinated and other organic solvents.

Katherine N. Probst, a fellow in the Center for Risk Management (CRM) at RFF, notes that cleanups of NPL sites have been criticized for costing too much and achieving too little. She points out that there is little consensus among different interest groups about the appropriate extent of remedial efforts under the Superfund program because there is disagreement about the fundamental purpose of the program. Arguments about whether actions to contain site contaminants are acceptable, asserts Probst, are really arguments about whether our national policy regarding site cleanups should be simply to reduce human exposure to contamination or to destroy or at least permanently immobilize contaminants.

Claims that the costs of cleanups outweigh the benefits are sometimes based on a narrow definition of benefits—the quantitative health risk reduction that cleanups achieve—says Probst. She and other researchers at RFF maintain that this definition may ignore some of the cleanup goals the public cares about, such as restoring land to its precontaminated state. In their analysis of the benefits and costs of Superfund site cleanups, Probst, CRM director Terry Davies, research associate Janet Stone, and consultant Dominic Golding have developed a typology of benefits that is qualitative rather than quantitative in nature. They are using the framework to identify the benefits and document the costs that ensue from cleanups at 25 NPL sites. This research is expected to provide new insights regarding the benefits garnered under the nation's current policy for Superfund site cleanups and the relationship between the benefits and costs of different policies for such cleanups.

Probst says the tour of Tysons Dump allowed RFF researchers to gain first-hand knowledge of the trade-offs involved in cleanups under Superfund. "When you visit Tysons Dump," she notes, "you notice first that the site is in a residential neighborhood, which is of concern; on the other hand, when you hear what is being done at the site, it is difficult not to question whether it is really worth spending millions of dollars to clean up the site."

Photo courtesy of Molly K. Macauley

RFF researchers donned boots before touring Tysons Dump. The Superfund site's groundwater and soils, which are contaminated with chlorinated and other organic solvents, pose a potential health hazard and a potential threat to a nearby wetland and aquifer.

About contributions to RFF

Resources for the Future sustains its programs through its endowment and through income from foundations, government agencies, corporations, and individuals. RFF accepts grants on the condition that it is solely responsible for the conduct of its research and the dissemination of its work to the public. RFF does not perform proprietary research.

All contributions to RFF, a publicly funded organization under Section 501(c)(3) of the Internal Revenue Code, are tax deductible. If you would like more information about contributions to RFF, please contact Debra Montanino, Director of External Affairs, Resources for the Future, 1616 P Street, NW, Washington, DC 20036-1400. Telephone: 202-328-5016. Fax: 202-939-3460.

Recent contributions and grants

Resources for the Future has recently received several grants from private foundations. The Summit Foundation awarded $25,000 to the Center for Risk Management for support of a project to develop a more complete and useful definition of risk in the context of setting environmental priorities. The Pew Charitable Trusts awarded $50,000 as part of its overall commitment of $350,000 to the center's rational risk reduction program. The David and Lucile Packard Foundation awarded Resources for the Future $15,000 for support of research on the sustainable use of land.

The following individuals have recently made gifts of $100 or more in support of research and education programs at Resources for the Future:

Peder Andersen, Robert A. Becker, Peter F. Benzing, Thomas H. Birdsall, Jose A. Catoggio, Willy Chazan, Benjamin Chinitz, Michael Edesess, James R. Ellis, John W. Firor, Jerry D. Geist, Alberto Goetzl, Kenzo Hemmi, Tetsuya Imai, Matthew Kahn, Kenneth L. Lay, Jack N. Lewis, Gay H. Orcutt, Edward L. Phillips, Anthony Picadio, James A. Roumasset, John W. Rowe, William D. Ruckelshaus, Lauren K. Soth, Simon D. Strauss, Russell E. Train, Peter F. Watzek, Melvin M. Webber, Walter Wilds, Mason Willrich, Elizabeth A. Wilman

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Weyerhaeuser Company Foundation

Using Economic Incentives to Reduce Air Pollution Emissions in Central and Eastern Europe: the Case of Poland

Michael A. Toman

A recent case study of the cost-effectiveness of different policies for controlling air pollution emissions in Poland suggests that the potential benefits of incentive-based (IB) policies, such as emissions fees and emission permit trading, are significant. For example, the study indicates that emissions from large stationary air pollution sources can be controlled at less cost through the use of IB environmental policies than they can be through the use of command-and-control environmental policies. However, the magnitude of the cost savings of IB policies is limited in Poland by several factors. The study also indicates that emission permit trading should be used to complement emissions fees, which are already charged in Poland. However, the legal status of such trading must be clarified.

Like other countries in Central and Eastern Europe, Poland faces the twin challenges of improving its environmental quality while also strengthening its economy during the transition to a market system. One way to reconcile these objectives, as policy analysts have long argued in the West, is to use economic incentives to control pollution. By giving polluters an economic stake in reducing emissions and the flexibility to find least-cost control methods, the argument goes, incentive-based (IB) policies can achieve any specified set of emissions reduction objectives at a minimum total cost to society. To harness economic incentives for pollution control, analysts have advocated the use of emissions fees and the institution of a system of tradable emission permits. A tradable emission permit system establishes a ceiling on total emissions and an initial distribution of allowed emissions among polluters, who can then buy and sell their emission rights. The system thus encourages polluters with the smallest pollution abatement costs to make the greatest pollution reductions.

While the application of such policies in Central and Eastern Europe may seem to be a natural marriage of economic and environmental interests, there are several challenges to consider. Perhaps the biggest challenge is that IB environmental policies are designed to work in countries where polluters actively respond to economic incentives. Even within the context of an established market economy, economic incentives can be distorted by the regulation of product prices and the investment decisions of polluting firms, such as electric utilities. In the emerging market economies of Central and Eastern Europe, the applicability of IB environmental policies is an even more complex issue than in established market economies because the power of economic incentives remains unclear. In particular, continued government intervention in the activities of large state-owned enterprises, which are often the major polluters in a given region, casts a shadow over the use of IB policies.

The application of IB environmental policies poses operational challenges as well. These challenges arise in connection with the monitoring of pollution and the enforcement of pollution standards. Where monitoring is inadequate, even command-and-control (CAC) environmental regulations—in which regulators specify the amounts of pollution individual polluters should cut or the types of pollution control technology to be used—are problematic. By comparison, IB policies require somewhat greater monitoring. To ensure the integrity of emission permit trading, for example, the emissions and permit holdings of individual polluters must be carefully tracked. Legal authority for IB policies must also be clearly established.

The applicability of incentive-based environmental policies is a more complex issue in the emerging market economies of Central and Eastern Europe than in established market economies because the power of economic incentives in the former remains unclear.

In the face of these challenges, two questions arise: First, how large are the potential gains resulting from IB environmental policies compared with those resulting from CAC environmental policies when both types of policies are used to achieve the same environmental goals? If the gains are modest, then efforts devoted to overcoming the economic and institutional obstacles to IB policies might better be spent on addressing other pressing problems. Second, if the gains are worth pursuing, how can these economic and institutional obstacles be overcome in practice?

A study I conducted with Robin Bates of the World Bank and Janusz Cofala of the Polish Academy of Sciences and the International Institute for Applied Systems Analysis in Laxenburg, Austria, attempts to answer these questions. It examines different policies for controlling air pollution emissions in Poland, and it suggests that, in that country, the potential benefits of IB policies appear worth pursuing.

Air pollution control problems and policies in Poland

Our study focused on three main types of primary air pollutants associated with energy use: particulates, nitrogen oxides (NO_x), and sulfur dioxide (SO_2). Each of these pollutants is believed to cause significant environmental damages, although the precise nature and extent of these damages remain unclear. Particulates are known to be a serious human health threat. Sulfur dioxide and nitrogen oxides in acid rain cause ecological damages. In addition, SO_2 converts to atmospheric sulfate particulates that are part of the particulate stream, and NO_x combines with volatile hydrocarbons to produce harmful ground-level ozone.

A large percentage of the above pollutants derives from fossil fuel combustion. The magnitude of the problems caused by the pollutants in Poland is related in turn to the energy intensity of the Polish economy and the lack of effective pollution controls. The energy intensity of gross domestic product (GDP) in Poland is much higher than that in the countries of Western Europe. This intensity reflects the legacy of central economic planning, in which physical production of all commodities—including energy—took precedence over environmental concerns; use of Poland's large endowment of coal, particularly low-grade lignite, was extensive; and economic incentives in the command economy for energy efficiency were lacking. Poland's high energy intensity of GDP and lack of effective pollution controls are reflected in the fact that the ratios of particulate, NO_x, and SO_2 emissions to GDP in Poland are many times greater than those in Western Europe.

While it is commonly believed that environmental degradation is ubiquitous in Poland and other Central and Eastern European countries, in actuality environmental conditions vary considerably across and within these countries. Air pollution in the region of Upper Silesia in southern Poland—and particularly in the areas around the cities of Katowice and Krakow—has been truly dreadful, although it has diminished somewhat as a result of the sharp economic contraction Poland has experienced in recent years. With the exception of areas immediately downwind of particularly dirty pollution emitters, air pollution appears to be at least somewhat less serious in other regions of Poland.

It is also commonly believed that pollution control policies were nonexistent in Central and Eastern Europe until recently. However, Poland charged emissions fees before the political transitions that began in 1989. In 1990, Poland's Ministry of the Environment passed the Ordinance on the Protection of the Air Against Pollution. Under the ordinance environmental standards govern both overall air quality (ambient standards) and the discharges of large factories, power plants, and other large polluters (source standards). Because these standards do not specify the types of technologies that must be used to abate pollution, polluters in Poland enjoy a degree of flexibility in mitigating their air pollution. This flexibility increases the cost-effectiveness of Poland's pollution control system, at least in principle. Since 1989, Poland has also raised its emissions fees (and fines set at a multiple of the regular fees). The increase, which more than offsets inflation, suggests that the fees make some contribution to improving Poland's air quality. Poland's system for monitoring compliance with air quality standards, while far from perfect, is improving.

These observations notwithstanding, there are several problems with Poland's air pollution control policies. First, emissions fees remain low in many cases, indicating that they are more effective in raising revenue (which can be used to ameliorate the effects of past pollution damage or to address other problems) than in inducing polluters to reduce emissions. Second, emissions fees and fines are not enforced in numerous instances because of the practical difficulty of imposing additional costs on enterprises already struggling with economic restructuring. Third, legal issues cloud the application of IB air pollution control policies. Specifically, the Ordinance on the Protection of the Air Against Pollution does not clearly establish the legal basis for emission permit trading among polluting firms. As currently interpreted, the ordinance allows trading among pollution sources within enterprises—among boilers within a power plant, for example. However, it leaves unsettled the scope of trading among polluters. While it has been interpreted as allowing trading among polluters in close proximity to each other, such trading does not appear to be occurring.

Calculating the relative costs of IB policies and CAC policies

In our investigation of the cost-saving potential of IB air pollution control policies, we used a dynamic simulation model that calculates energy use and emissions of air pollution in Poland over five-year intervals from 1990 to 2015 under a variety of emissions control policies. The model, developed at the Polish Academy of Sciences, starts with a scenario reflecting the predictions of experts in Poland concerning economic development and changes in the efficiency of end uses of energy over the period. These predictions give rise

to projections of final energy demand—that is, the demand for energy by households, businesses, and other end users of energy—over time. Given these energy demand projections and a specified set of environmental constraints, the model then calculates the least-cost energy supply and energy conversion activities that would be needed to satisfy final energy demand.

The social costs of air pollution control include the reduction in consumer surplus that would result from an increase in energy prices and a decrease in final energy demand caused by pollution control policies.

Implicit in the use of a model of least-cost final energy supply is the assumption that Poland is moving toward a well-functioning energy market in which producers and consumers will pay the full economic costs of energy (plus any applicable excise taxes). Given the pace and direction of economic restructuring in Poland, this assumption seems reasonable. While the baseline energy demand scenario in the model is fixed, the model does allow for variations in energy demand relative to the baseline scenario. Such variations would reflect the effects of emissions taxes or the cost of emission permits in meeting energy demand.

The model includes a highly disaggregated representation of energy supply and conversion technologies as well as options for air pollution control. With respect to the former, for example, it distinguishes among the various energy production technologies used by power plants. With respect to the latter, it distinguishes among emissions control technologies (such as SO_2 scrubbing) as well as among emissions reduction strategies (such as replacing coal use with natural gas use and constructing power plants that have increased energy efficiency and decreased emissions per unit of fuel use).

Because the model is designed to calculate energy use and air pollution emissions at a national level, and because it does not specify the location of specific polluters or how the emissions generated by these polluters affect ambient environmental conditions, it cannot show the effect on ambient air quality of different environmental policies. Nevertheless, we believe that our comparisons of such policies give some indication of the potential benefits garnered by IB policies.

In order to measure the cost-saving potential of IB policies, we established a command-and-control regulation baseline. This CAC regulatory scenario includes emissions standards for large stationary pollution sources that are based on the source standards established by the Ordinance on the Protection of Air Against Pollution. It also includes some controls on coal burning by households (namely, the gradual elimination of this activity in urban areas) and on emissions from the transport sector (most prominently, the installation of catalytic converters in motor vehicles) that are not stipulated in the ordinance.

We then compared four IB policies with this CAC scenario. The first three of these policies have the same total emissions targets as the policies in the CAC scenario; the fourth does not. The first IB policy retains the CAC scenario's controls on coal burning by households and on emissions from the transport sector, but requires large stationary pollution sources to pay fees on emissions of particulates, NO_x, and SO_2 in order to achieve the total emissions reductions that would be attained under the CAC scenario. The second IB policy relaxes all the CAC scenario's fixed controls on pollutant emissions, including those on coal burning by households and on emissions from the transport sector, and relies on emissions fees paid by large stationary pollution sources and on energy taxes paid by mobile air pollution sources (such as cars) and small air pollution sources (such as homes) to achieve the total emissions reductions that would be attained under the CAC scenario. In order to make the energy taxes equivalent to the emissions fees, the taxes are based on the average volume of pollutant discharges per unit of fuel use. The third IB policy allows large stationary pollution sources to engage in SO_2 emission permit trading at the national level but maintains the CAC scenario's restrictions on particulate and NO_x discharges from these sources. It also maintains the CAC scenario's controls on coal burning by households and on emissions from the transport sector. The fourth IB policy relies on a 100 percent tax on coal use to achieve emissions reductions. In selecting this policy for our analysis, we were interested in exploring the effects of a narrowly targeted tax rather than in attempting to equate the total emissions reductions that would be achieved by the policy with those that would be attained by the CAC scenario.

We compared these four IB policies with the CAC scenario on the basis of social costs (see table, p. 21). These costs include the costs of abating emissions from large stationary pollution sources and the costs of controls on coal burning by households and on emissions from the transport sector. They also include the reduction in consumer surplus that would result from an increase in energy prices and a decrease in final energy demand caused by the pollution control policies.

Results of cost comparisons

Simulations of our model reveal that the application of IB policies to large stationary pollution sources will garner cost savings, but that the magnitude of the savings is limited by two factors that reflect—at least in part—efficiencies already embodied in the CAC scenario. First, as noted above, the CAC sce-

nario's emissions control standards for such sources are based on source standards that do not prescribe the use of particular pollution control technologies. Thus polluters can realize some cost savings under the CAC scenario by choosing the technologies that are least expensive for them. Second, an implicit assumption of our model is that individual firms are free to choose how to distribute pollution abatement efforts among the pollution sources they control—for example, among boilers within a power plant. This assumption reflects a broad interpretation of the possibilities for intrafirm emission permit trading under the Ordinance on the Protection of Air Against Pollution. Given a narrow interpretation of the ordinance's source standards, firms' flexibility to choose pollution control strategies is limited, and the cost-saving potential of IB policies is increased.

Another implicit assumption of our model leads to an understatement of the cost-saving advantages of IB policies. This assumption is that all the technologies that could be used to abate pollution have already been developed. It does not reflect the fact that IB policies provide dynamic incentives for the development of technologies that would abate pollution at less cost than existing pollution control technologies.

While simulations of our model reveal that the cost savings garnered by the application of IB policies to large stationary pollution sources are limited, they indicate that substantial cost savings can be attained through the use of emissions fees and fuel taxes on all pollution sources and the relaxation of rigid controls on coal burning by households and on emissions from the transport sector. Compared with increased controls on emissions from large stationary pollution sources, the controls on emissions from the transport sector are an expensive means for achieving emissions reductions. Relying only on fuel taxes makes it possible to find a relatively low-cost combination of pollution abatement efforts—most likely, less such efforts by the transport sector and more such efforts by large stationary pollution sources. However, controls on small air pollution sources and mobile air pollution sources in urban areas might still be necessary to satisfy local ambient air quality standards, even if they are expensive.

Two other outcomes of the model simulations are noteworthy. First, the emissions fees that are required under the first and second IB policies in order to achieve the emissions reductions attained under the CAC scenario are more than an order of magnitude larger than the emissions fees currently used in Poland. Second, the coal tax (the fourth IB policy) is almost as costly as, but far less effective in reducing emissions than, the other three IB policies

Social Costs of Pollution Control in Poland under Command-and-Control and Incentive-Based (IB) Environmental Policies, 1991-2015

Components of social costs	Command-and-control scenario	Emissions fees imposed on large stationary pollution sources (IB policy #1)	Emissions fees imposed on large stationary pollution sources and energy taxes imposed on small and mobile pollution sources (IB policy #2)	Trading of sulfur dioxide emissions permits by large stationary pollution sources (IB policy #3)	Tax on coal use (IB policy #4)
Pollution control costs of large stationary pollution sources and loss of producer surplus	6.57	5.30	5.51	5.87	9.76
Loss of consumer surplus from reduced energy use	0.02	0.02	0.22	0.02	1.04
Costs to urban households switching from coal to gas	0.08	0.08	—	0.08	—
Cost of pollution controls on the transport sector	5.89	5.89	—	5.89	—
Total	**12.56**	**11.29**	**5.73**	**11.86**	**10.80**

Note: All figures represent costs in billions of 1990 U.S. dollars. Each figure represents the total cost of the given component of social costs, discounted at the rate of 12 percent, over the 25-year period between 1991 and 2015.

and the CAC pollution control strategy. This finding highlights the importance of a comparatively more broad-based emissions reduction strategy.

Implementing incentive-based environmental policies

Our case study of air pollution control strategies in Poland indicates that IB policies can generate cost savings that are, at minimum, nontrivial and possibly substantial; but how can these savings be achieved in practice? Which IB policies are likely to be most effective under the economic circumstances encountered in the transition to a market-based economy?

Emissions fees might be favored in Poland because they already are well established in Polish law and because they generate revenues that can be used to ameliorate pollution or to attain other social goals. However, there are several well-known disadvantages to their use. First, such fees lead to the transfer of substantial revenues from polluters to the government, and polluters therefore oppose raising them. In simulations of our model, emissions fees increased the private cost of compliance with environmental standards by about 75 percent. Second, emissions fees may not have the desired effects in a setting in which enterprises receive budget subsidies from the government and in which the state will either indirectly subsidize emissions fees or not enforce them.

Given these disadvantages, tradable emission permits may be an important complement to the emissions fees currently charged in Poland. A program of nationwide emission permit trading, like the SO_2 emission control program enacted in the United States under the Clean Air Act Amendments of 1990, requires relatively careful monitoring of individual firms' emissions and permit holdings, as noted above, as well as a substantial number of well-informed market participants who are capable of making sophisticated trade-offs. However, less ambitious programs based on a system of bilateral emissions trading also have substantial promise in an economic setting such as Poland's. Under such a system, individual polluters can seek out trading partners in ad hoc fashion (without a formal market mechanism or formal tradable emission rights issued by regulators) in order to find mutually advantageous arrangements. Such arrangements are those wherein a polluter with low pollution abatement costs makes emissions reductions greater than those required by law in exchange for financial compensation from a polluter with high pollution abatement costs. Such arrangements can be conditioned on a requirement that a total emissions reduction goal is attained and that overall air quality in any one area is improved.

In Poland, bilateral emissions trading may be an important complement to emissions fees in controlling air pollution; under such a trading system, a polluter with low pollution abatement costs makes emissions reductions greater than those required by law in exchange for financial compensation from a polluter with high pollution abatement costs.

Bilateral emissions trading will not result in the exploitation of all possible cost-effective reallocations of responsibility for pollution control. Nevertheless, analyses of comparable trading opportunities in the United States generally indicate that such trading can lead to significant cost savings in pollution abatement efforts. However, these analyses also suggest that the cost-saving potential of bilateral emissions trading tends to be diminished when government restrictions encumber exchanges of permits. Thus the cost-effectiveness of such trading would be enhanced if the legal status of emissions trading were clarified and if government restrictions on exchanges were limited.

There are several potential obstacles to emissions trading in Poland. One obstacle, as noted above, is that the legal status of such trading in Poland is unclear. Another is that incentives to engage in emissions trading would be limited if the government fails to enforce air quality standards or interferes with the economy in ways that weaken firms' interest in minimizing pollution control costs. Under such circumstances, however, any pollution control policy—including emissions fees and CAC regulation—is doomed to failure.

Policy recommendations

Despite the potential obstacles to its success, emissions trading appears to be an important complement to emissions fees in controlling air pollution in Poland. Although such fees stimulate some pollution abatement activities and provide a source of revenue for mitigating environmental damages generated in the past, it is doubtful that they can be raised to the level necessary for Poland to attain its current air quality standards. This point is underscored by the fact that no country in the West has yet managed to raise its emissions fees high enough to rely on the fees to achieve its environmental goals. Thus it seems vital to develop the legal and economic institutions needed to support increased emissions trading. Such trading could start with informal bilateral exchanges, as discussed above, and progress to more formal and multilateral exchanges as Poland's economic and regulatory institutions develop.

It should be noted that the cost-saving potential of emissions trading in Poland might be greater or smaller than

our case study indicates. In the study we focused only on how alternative air pollution control policies will affect total air pollutant emissions in Poland. However, the effectiveness of such policies needs to be gauged by how the policies affect actual air quality—that is, ambient pollution concentrations in different locations—as pollution damages depend on ambient conditions. Thus, to improve our understanding of the cost-effectiveness of IB environmental policies in Poland and in other Central and Eastern European countries whose economies are in transition, it is necessary to extend our analysis to an examination of emissions trading in light of local ambient standards and the way pollutants are dispersed as a result of meteorological phenomena. Such an examination will allow us to quantify more accurately the gains from emissions trading under trading rules that reflect how emissions from different pollutant sources affect ambient conditions at different locations. An analysis of this kind by the World Bank has already begun in the Polish city of Krakow.

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Tradable Sulfur Dioxide Emission Permits and European Economic Integration

Dallas Burtraw

An international system of tradable emission permits has engendered interest as a way to control emissions of sulfur dioxide (SO_2) in Europe. Like other forms of incentive-based regulation, emission permit trading has the potential to achieve a given emissions reduction goal at less cost than command-and-control regulation. However, the full cost-saving potential of SO_2 emission trading in Europe's electricity industry, which generates 65 percent of Europe's total SO_2 emissions, is significantly undermined by the structural and regulatory diversity of that industry. Despite this fact, emission permit trading can be justified on the ground that it would promote the reflection in electricity prices of the social costs of pollution resulting from electricity generation. The internalization of social costs in these prices is critical to Europe's realization of economic unification and to the liberalization of European energy markets.

Emissions of sulfur dioxide (SO_2) are thought to contribute to acidification of soils and water, deterioration of visibility, and corrosion of materials; they are also thought to aggravate respiratory problems in humans. One possible approach to the control of SO_2 emissions is the trading of SO_2 emission permits on an international level. In 1990 the United States initiated the largest experiment of this type of environmental regulation in history by adopting a national system of SO_2 emission permit trading.

A system of tradable emission permits typically works as follows. A cap is set on total emissions of a given pollutant in a given geographic area, and a fixed number of permits to emit some quantity of the pollutant is issued to the pollutant emitters, who can then trade the permits among themselves. In theory, those who find that their pollution abatement costs are relatively low will choose to reduce their emissions and sell their unneeded permits, while those who find that their pollution abatement costs are relatively high will choose to buy permits rather than to reduce their emissions. Ideally, decisions about whether or how much to invest in pollution abatement and in permits will depend on the relative cost of each.

Two potential benefits are often ascribed to a system of tradable emission permits. The first is that such a system allows an environmental objective to be achieved at least cost. The second is that, because the price of emission permits tends to be reflected in the price of final products and services, individuals are encouraged to consider the social costs of pollution in their consumption decisions.

The first of these benefits will be difficult to obtain through the trading of SO_2 emission permits within Europe's electricity industry, which is a major focus of SO_2 emissions control efforts in Europe. The lack of incentives to minimize costs and other obstacles to emission permit trading in that industry suggest that the cost savings of such trading may not be fully realized. Nevertheless, the fact that SO_2 emission permits can lead to the internalization of social costs in the price of electricity provides a compelling reason to pursue emission permit trading.

SO_2 emissions reduction and electricity markets

Among the most important efforts to curb SO_2 emissions in Europe to date are a protocol issued by the United Nations Economic Commission for Europe (UNECE) in 1985 and a directive adopted by the European Community (EC) in 1989. The protocol—which was signed by 21 countries, not including Poland and the United Kingdom, and ratified by 16 countries in 1987—calls for UNECE member countries to reduce their annual level of SO_2 emissions by at least 30 percent of levels in 1980. The Large Combustion Plant Directive specifies percentage reductions in emissions of sulfur dioxide and nitrogen oxides for each EC member country and places specific limits on such emissions from power plants.

According to researchers at the International Institute of Applied Systems Analysis (IIASA) in Laxenburg, Austria, the combined effect of current SO_2 emissions control commitments on the part of European countries will be to reduce Europe's total annual SO_2 emissions in 1995 by perhaps 29 percent of levels in 1980. However, a reduction of 50 percent to 70 percent of 1980 levels must be attained in order to reverse soil acidification caused by sulfur deposition.

By the year 2000, sulfur dioxide emissions are expected to decline significantly in the northern and western regions of Europe and to decline somewhat less significantly in the countries of Central and Eastern Europe. However, they are expected to increase in the southern region of Europe, the countries of which have not yet committed to any SO_2 emissions reductions targets.

The attention given SO_2 emissions reductions by many European countries reflects a concern about environmental protection in general. In turn, this concern has been reflected in economic unification efforts. For instance, the Single European Act (SEA) of 1987 placed protection of the environment on an equal footing with economic growth, free trade, and policies to encourage competition. The Treaty on Political Union has further strengthened political consideration of the environment in the EC. As both the treaty and the SEA suggest, the EC—which has replaced member states as the initial source of environmental regulations—recognizes that economic growth as a consequence of economic unification will have environmental implications.

With regard to reducing SO_2 emissions, the question at hand is how the EC's commitment to environmental protection will affect Europe's path toward economic integration and vice versa. Since approximately 65 percent of all SO_2 emissions in Europe originate from the generation of electricity, the structure and regulation of European electricity markets will be an especially important factor in determining how SO_2 emissions reductions will be achieved. Historically, financial subsidies have played an important role in European markets for electricity and other forms of energy. These subsidies have cost European taxpayers billions of European currency units (ECUs) over the years. The EC has claimed that the buying and selling of electricity among EC member countries could produce cost savings of between 1.5 billion and 3 billion ECUs per year and that an internal market for all forms of energy could lead to savings of 0.5 percent to 1 percent of gross domestic product across the EC. An open international electricity market is expected to be developed in several phases. In the market, EC member states will retain authority for electricity system planning and all aspects of electricity pricing.

Benefits of tradable emission permits

There are two reasons why tradable emission permits have attracted more interest than emission fees and other forms of incentive-based (IB) environmental regulation as a means for regulating SO_2 emissions in Europe. First, under an emission permit trading system, the EC could directly control the total level of SO_2 emissions in Europe by restricting the number of permits it issues to SO_2 emitters. Second, by constraining trading in certain areas or by certain polluters, it could control the level of such emissions in the locations that suffer the most from the environmental and health effects of sulfur deposition.

Two potential benefits of an emission permit trading system are the cost-effective achievement of a given emissions reduction goal and the internalization of the social costs of pollution in the prices of goods and services.

As noted above, there are two potential benefits of an emission permit trading system. The most commonly cited benefit is the attainment of productive efficiency—that is, the cost-effective achievement of a given goal. Emission permit trading (and other forms of IB environmental regulation) can often achieve a given environmental goal at less cost than command-and-control (CAC) regulation of emissions. Unlike CAC regulation, under which regulators might specify use of the best-available pollution control technology, emission permit trading encourages the development of both production technologies and pollution control technologies that in the future would reduce the cost of complying with emissions limits set by regulators.

The second potential benefit of emission permit trading is that it helps to

internalize in the prices of goods and services the costs to society of pollution emitted after firms have complied with environmental laws. Under CAC regulation, this residual pollution remains unpriced because firms are given free-of-charge access to the land, air, or water that assimilates it. As a consequence, society demands too much electricity because the price of electricity is too low. Under an emission permit trading system, firms must pay through the purchase of emission permits for access to the environmental media that assimilate their residual pollution. The resulting pricing of residual pollution raises product prices and causes secondary adjustments in economic behavior, such as decreases in consumer demand, that promote efficiency in the allocation of resources to economic activities.

Obstacles to emission permit trading

Simulations of SO_2 emission permit trading in Europe conducted by IIASA and others indicate that such trading could greatly reduce the costs of meeting Europe's SO_2 reduction goals. One opportunity for reducing these costs stems from the fact that EC member states often pursue pollution abatement strategies that subsidize important domestic constituencies but that do not obtain pollution reductions at least cost. Another opportunity for reducing costs stems from the considerable differences across the EC in preexisting emission standards that form the benchmark for percentage emissions reductions required by the Large Combustion Plant Directive. The disparities in marginal abatement costs produced by these differences could be exploited in a system of emission permit trading. Under such a system, a country could determine whether it would be cheaper to reduce its emissions by a given amount or to compensate another country for reducing its emissions by the same amount, and act accordingly. Unfortunately, neither of these two opportunities to reduce costs is likely to be exploited in the implementation of emission permit trading in Europe's electric industry.

Among European countries, asymmetries in the nature of regulation and in incentives to pursue specific environmental compliance options will tend to undermine the economic principles of an emission permit trading system.

Virtually all analyses of the potential savings from emission permit trading and other forms of IB regulation have been limited to examinations of competitive product markets or to the role of market power on behalf of producers in an unregulated product market. These analyses depend fundamentally on the expectation that firms will respond to economic incentives by choosing a least-cost strategy for compliance with environmental standards. With regard to the electricity industry in Europe, this expectation may not be realistic for several reasons.

European electric utilities may not have the incentive to maximize profits or to minimize costs that competitive firms have. State-owned electric utilities might lack incentives to minimize costs for several reasons. First, doing so might cause their production targets to be increased by the government in the future. Second, they are protected by the government from financial failure through subsidies, tax exemptions, easily obtained credit, and other forms of financial aid. Thus their survival and growth may depend more on their relation to the current government bureaucracy and on certain aspects of their performance that are of concern to society than to success in the market.

Privately owned electric utilities might also lack incentives to minimize costs. With the exception of those in England, almost all privately owned utilities in Europe are lightly regulated monopolies that typically recover all their costs through tariffs. Because they are not subject to prudence reviews that can lead to the disallowance of some costs, they can engage in pricing that approximates cost-plus pricing, in which firms pass along all costs to consumers. In some instances, such as when prices are based on standard rather than on actual costs, they will have a modest incentive to reduce costs.

There are two other reasons why the potential cost savings of emission permit trading are unlikely to be realized. First, firms that are regulated typically do not make decisions on the basis of market prices, but rather on the basis of distorted opportunity costs that reflect regulatory practices. Implicit in the current regulatory practices of European countries are biases in the treatment of depreciation, recovery of capital costs, risk associated with investments, and fluctuating production input prices.

The cost-saving potential of emission permit trading and other forms of incentive-based environmental regulation is diminished in Europe's electricity industry because European electric utilities may not have the incentive to maximize profits or to minimize costs that competitive firms have.

Asymmetries among European countries in the nature of regulation and in incentives to pursue specific environmental compliance options will tend to undermine the economic principles of

an emission permit trading system. Second, regulators in each country are likely to favor explicitly certain types of compliance activities that promote social objectives other than the control of pollution at least cost.

Investment behavior on the part of all electric utilities is affected by the national energy policies of European governments, which have played an increasingly important role in planning electricity-generating systems and in making decisions about new investments in the electricity and other energy sectors of their national economies since the early 1970s. Energy policies have been and continue to be used as a tool for macroeconomic policies and for policies aimed at providing aid to specific fuel industries. For example, energy policies in Spain, England, and Germany support the use of coal; those in the Netherlands support the use of gas; and those in France support the use of coal and nuclear energy. Such policies clearly discourage the implementation of efficient cost control practices.

One way to overcome, at least in part, the lack of incentives to minimize costs in the electric industry is to promote the EC goal of making electricity pricing transparent—that is, distinguishing among the various components of delivered electricity services and explicitly accounting for the costs embedded in each component. Transparent pricing of electricity has two benefits. First, it discourages subsidization of electricity generation technologies, because the costs of the technologies are open to public review and criticism. Second, it promotes competition in electricity markets by helping to establish the relative cost advantages of technologies.

In the United States an element of price transparency is provided by the Uniform System of Accounts, which recommends accounting practices to state regulators. As the EC moves toward an internal energy market and increased economic integration with the rest of Europe, the establishment of a similar institution in Europe would promote emission permit trading by helping to make assymetries in the regulation of electric utilities apparent. A template for consistent cost accounting in the electric industry should be developed as part of an international agreement for SO_2 emission permit trading across Europe.

Emission permit trading in an international economy

Despite the many obstacles to minimizing emission reduction costs through emission permit trading, such trading should remain of interest because it has a significant virtue. It and other forms of incentive-based environmental regulation allow decision makers to consider social costs in the context of their own opportunity costs and, depending on how product prices are set, to reflect social costs in product prices. In internalizing social costs in the price of electricity, emission permit trading is consistent with the economic objectives of the EC—free trade and economic competition—and with the economic integration of Europe. However, strategic considerations in the implementation of international environmental policies may undermine this virtue of emission permit trading. These considerations suggest that international environmental agreements must not only specify environmental goals but also articulate the mechanism through which such goals are to be achieved.

In internalizing social costs in the price of electricity, emission permit trading is consistent with the economic objectives of the EC—free trade and economic competition—and with the economic integration of Europe.

Consider an international agreement for SO_2 emissions control that specifies (potentially tradable) emission targets for each country but leaves the mechanism for achieving the targets up to the individual country. Is there reason to believe that, acting unilaterally, national governments would implement national systems of tradable emission permits? A country's firms may find it cheaper to comply with such IB regulation than to comply with CAC regulation, but their cost savings must be weighed against the reduction in their international competitiveness that would result from the effect of emission permit trading on their product prices. This effect, as noted above, is to raise product prices by including in the prices not only the marginal cost of pollution control but also the opportunity cost of using the atmosphere's absorptive capacity. The distinction between marginal and average costs makes a direct comparison of emission permit trading and CAC regulation in Europe difficult, but it is probable that a firm's opportunity cost in purchasing an emission permit—a cost reflected in the monetary value of the permit—would be higher than the firm's savings in environmental compliance costs under emission permit trading. In this case, the national benefits that result from competitive pricing under CAC regulation might outweigh the benefits that result from savings in pollution control costs under IB regulation. Furthermore, the benefits to individual firms that utilize comparatively more polluting technology might be greater than those to firms that utilize comparatively less polluting technology.

Hence, absent a specific mechanism to implement IB environmental regulation as a component of international environmental agreements among European countries to reduce SO_2 emissions, it is unlikely that national governments of Europe will unilaterally adopt such regulation. As a result, the

costs of achieving environmental goals may be higher than they need to be, and the necessary precepts for the economic integration of Europe—namely, transparent pricing of electricity and the elimination of subsidies implicitly provided by some national environmental policies—may be undermined.

Because the benefits that result from competitive pricing under CAC regulation may outweigh the benefits that result from savings in pollution control costs under IB regulation, it is unlikely that countries will unilaterally adopt a national system of emission permit trading.

Given these potential consequences, it makes sense for the countries of Europe to pursue a system of tradable SO_2 emission permits on an international level. A critical issue in implementing such a system will be the initial distribution of emission permits. In order to realize cost savings through the exploitation of marginal emissions abatement costs, the permits should be distributed directly to electric utilities and other SO_2 emitters rather than to national governments. If permits are initially allocated to nations, there is no guarantee that the price of a permit or the opportunity cost of discharging a unit of SO_2 emissions would be passed on to industry or to consumers. Furthermore, it is likely that national governments would use CAC regulation that is consistent with their holdings of permits to achieve emissions standards set under an international environmental agreement. If so, governments would have an opportunity to subsidize domestic electricity utilities and other domestic industries that make extensive use of electricity.

One of the benefits of emission permit trading is that the allotment of permits can promote cost-sharing among countries that each bear different emissions control costs. Within the electric industry, the fuels used to generate electricity are an important factor in determining these costs. While there is great diversity among European countries in the fuels used to generate electricity, there is little diversity in the fuels any one country uses to generate electricity. The countries whose electric utilities rely on coal in generating electricity will bear the greatest costs to reduce SO_2 emissions. To lessen the cost burden of these countries, permits could be distributed on the basis of historic levels of emissions. However, this approach has one disadvantage. Given current regulatory practices, electricity prices would be unlikely to reflect the opportunity cost of using permits if the permits were distributed to electric utilities free of charge. An alternative approach is to distribute permits through an auction. However, coal-based electric utilities would oppose this approach. Thus it may be preferable to distribute the majority of permits as endowments, doing so on the basis of historic levels of emissions, and to auction the remaining permits. Over time the endowments could be phased out and replaced by an expanding auction. Revenues from permit auctions could then be allocated in ways that would lessen the burden of emissions control on the electric industry as a whole and on the countries bearing the greatest emissions control costs.

Importance of internalizing social costs

An international system of tradable emission permits will not be easy to implement in Europe. Economic integration of Europe is unlikely to lead individual countries to surrender control of their energy, environmental, and industrial policies. Moreover, each country is likely to continue to appease influential social interests within its borders.

Additional problems will lessen the prospects for achieving the benefits of SO_2 emission permit trading in Europe's electricity industry. Structural and regulatory diversity within this industry is an obstacle to realizing the full cost-saving potential of emission permit trading because it imposes regulatory biases that obscure the full social opportunity cost of tradable SO_2 emission permits. As noted above, the adoption of accounting practices that make this cost explicit and the distribution of emission permits to individual electric utilities rather than to national governments would help solve this problem.

Even if the full cost-saving potential of tradable emission permits cannot be realized in Europe's electricity industry, the internalization of social costs in electricity system planning and potentially in the price of electricity is sufficiently critical to advancing Europe's agenda of economic integration and liberalization of energy markets that it alone justifies emission permit trading. Such trading and other forms of IB regulation are the only kind of environmental regulation consistent with the economic objectives that have been set out in Europe. However, the lack of incentives for the countries of Europe to implement unilaterally SO_2 emission permit trading at a national level is an obstacle to the internalization of social costs in energy prices. In order for such internalization to occur, international negotiations on transboundary pollution must establish emission permit trading (or some other form of IB regulation) as the mechanism for achieving SO_2 emissions reduction goals.

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Cost-Effective Control of Water Pollution in Central and Eastern Europe

Charles M. Paulsen

Lack of controls on point sources of pollutant discharges—primarily sewage treatment plants—has contributed to the degradation of surface water quality in Central and Eastern Europe. Neither relying on existing pollution control nor adopting the West's best-available pollution control technology and minimum pollutant discharge policies is likely to be a feasible course of action for the region, as the environmental consequences of the former would appear to be unacceptable and the costs of the latter to be prohibitive. However, a recent case study involving the Nitra River basin in the Slovak Republic suggests that the region can realize substantial improvements in water quality at a fraction of the cost of command-and-control policies used in the West by taking into account the relative contributions to pollution and pollution control costs of individual point sources and basing pollution control efforts on those contributions and costs.

Since political transformations there in 1989, Central and Eastern Europe has increasingly come to realize the severity of the degradation of its surface water quality. Most major rivers and lakes in the region have pollutant concentrations far above international standards. In addition to posing health threats, contamination of the region's surface water has economic consequences. For example, pollutant discharges into the Baltic and the Black seas have already seriously reduced the output of once-productive fisheries.

Policies designed to improve the region's water quality will have to grapple with the declining industrial and agricultural output, concomitant decreases in material living standards, and shortages of investment capital faced by all the region's national governments. Given these conditions, the countries of Central and Eastern Europe could simply choose to delay adoption of the best-available pollution control technology and minimum pollutant discharge policies of Western Europe and North America until their economies can afford them. In the meantime, this decision would mean relying on existing pollution control facilities to deal with water quality problems caused by so-called point sources of water pollution—primarily industrial and municipal sewage treatment plants. As the region's economies improve, presumably more money would become available for the capital investments that are required for construction of sewage treatment plants with state-of-the-art pollution control. The region's governments would meanwhile stand to gain an advantage from delaying investment in water quality improvement: the longer they wait to undertake such investment, the greater the likelihood that noncompetitive industries will fail, obviating the need to invest in new or improved plants to treat the industries' sewage.

Delaying efforts to improve water quality is problematic, however. Although pollutant discharges into the region's waters can be expected to decrease as industries close, change their product mix, or update their production processes, it is likely that municipal sewage loads will increase as more and more households and newly formed businesses are connected to public water and sewer networks. In addition, the public may demand that water quality issues be addressed in the present rather than in the future. The downfall of many of the formerly Communist governments was brought about in part by environmental movements, and anecdotal evidence suggests that a substantial demand for improved environmental quality still exists in many Central and Eastern European countries.

Given poor surface water quality, a demand for improvements in such quality, and scarce financial resources, neither long delays in wastewater treatment nor immediate implementation of a minimum discharge policy is appropriate in Central and Eastern Europe.

One alternative to delaying water quality improvement efforts would be an immediate attempt to implement a minimum discharge policy, whereby sewage treatment plants would be required to reduce pollutant discharges into surface water in line with European Community (EC) standards for wastewater treatment. However, the cost of such a policy might well be more than governments in the region are willing (or able) to pay, given that the per capita cost of meeting such standards exceeds per capita gross domestic product (GDP) in three of five countries in Central and Eastern Europe (see table, p. 29). Although countries in the region might be able to borrow a portion of the capital investment required to construct new or improve existing sewage treat-

ment plants in order to meet EC wastewater treatment standards, it might not be wise for them to do so. Debt as a percentage of GDP is already high in many Central and Eastern European countries. Moreover, it is likely to increase as investment in industrial modernization and communications and transportation infrastructure proceeds.

Together, three factors—poor surface water quality, a demand for improvements in such quality, and scarce financial resources—suggest that neither long delays in wastewater treatment nor immediate implementation of a minimum discharge policy is appropriate. If the desire to improve surface water quality and the necessity of minimizing pollution control costs are important factors in decisions made by the governments of Central and Eastern Europe, a policy that attempts to improve water quality cost-effectively would seem to offer a means of realizing the most improvement per dollar invested.

Behavior of pollutants in river basins

Since most of Central and Eastern Europe's water supply is drawn from rivers, these bodies of water can be expected to be the primary focus of efforts to improve water quality. In order to understand which such efforts are likely to be cost-effective, it is necessary to take into account two behavioral patterns of pollutants in a typical river basin. To illustrate these patterns, suppose that our typical river basin has three point sources of pollutant discharges and three monitoring stations where water quality is measured, and that point source 1 is located highest upstream, followed further downstream by monitoring station A, point source 2, monitoring station B, point source 3, and monitoring point C (see figure, p. 30). The first behavior pattern to consider is that pollutants from each source of discharges into the basin move only in a downstream direction, resulting in higher quality of water upstream and lower quality of water downstream. Thus the quality of water passing by monitoring stations A, B, and C will be affected by pollutants discharged from point source 1, while the quality of water passing by monitoring station A will be affected only by pollutants discharged from point source 1. The second behavioral pattern to consider is that most conventional pollutants—nitrogen and phosphorus, for example—either decay naturally and so are effectively removed from the river as they move downstream or settle out of the water column and become entrained in the sediment of the river bed.

In order to understand which water quality improvement efforts are likely to be cost-effective, it is necessary to take into account that pollutants from each source of discharges into a river basin move only in a downstream direction and that most conventional pollutants either decay naturally or settle out of the water column.

The downstream movement and the natural decay or settling out of conventional pollutants in rivers have several implications for management strategies to enhance water quality. First, even if all point sources of a pollutant dis-

Resources of and Potential Costs in U.S. Dollars to Improve Water Quality in Central and Eastern Europe

County	Population (millions), 1992[1]	GDP (millions of dollars), 1992[1]	Per capita GDP, 1992[1]	Per capita cost to meet European Community water quality standards, 1992[2]	Total debt as percentage of GDP, 1991[1]	Percentage change in industrial production, 1990–1992[1]
Bulgaria	8.47	6,903	815	3,755	not available	–54
Former Czech and Slovak Federal Republic	15.66	36,093	2,305	4,927	27	–40
Hungary	10.30	35,494	3,446	2,116	78	–32
Poland	38.30	72,579	1,895	1,230	61	–32
Romania	23.20	14,152	610	1,422	not available	–54

[1] Figures are from *The Economist* (March 13, 1993)
[2] Figures are from *Der Standard* (June 17, 1993).

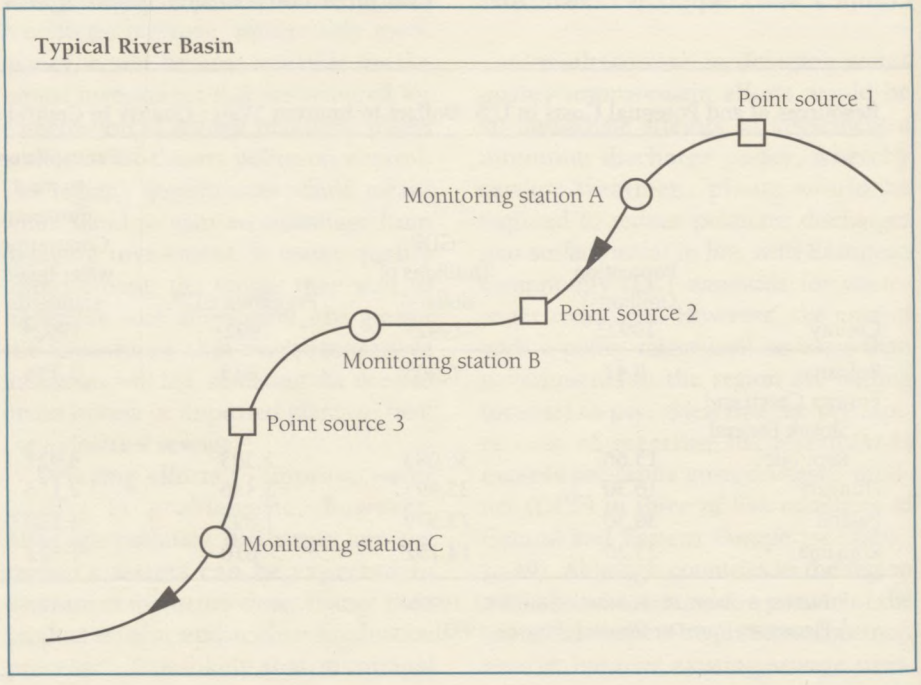
charge the same quantity of the pollutant into our typical river basin and cost the same amount to control (an extremely unlikely circumstance), the relative importance of each point source with respect to improving water quality at the critical monitoring station will differ. If the worst water quality is found at monitoring station A, only the control of discharges from point source 1 would make any contribution to improving water quality. If, on the other hand, the worst quality water is found at monitoring point C, control of discharges from point sources 1, 2, and 3 would contribute to water quality improvements. In the latter case, it is likely that discharges from point source 3 will have far greater effects on water quality at monitoring station C than will discharges from point source 1. Thus the location of point sources makes a difference in the effects of the point sources on water quality at various places in the river basin.

An analysis of potential pollution control policies that accounts for the location of pollution sources along a river basin may be needed to identify the policy that will meet ambient water quality targets in the most cost-effective way.

It is particularly important to consider differential effects on water quality due to the location of point sources when the financial resources needed to reduce pollutant discharges are scarce. When this is the case, an analysis of potential pollution control policies that accounts for the location of pollution sources along our typical river basin may be needed to identify the policy that will meet ambient water quality targets in the most cost-efficient way. If water sampled at monitoring stations B and C meets such targets, while water sampled at monitoring station A does not, a policy that attempts to achieve the requisite pollution control at least cost would focus on controlling pollutant discharges from point source 1. In the more likely case that water sampled at monitoring station C has the worst ambient quality, environmental authorities would need information on the relative contributions of all three point sources to water quality degradation, as well as on the relative costs of controlling discharges from each of the sources, in order to construct a policy that meets ambient quality standards at least cost. The basic idea is that the more a point source contributes to environmental degradation, the more it should control its pollutant discharges. Similarly, the less it costs a source to control its discharges, the more the source should control discharges relative to other sources.

Nitra River basin case study

A study I conducted with László Somlyódy of the International Institute for Applied Systems Analysis in Laxenburg, Austria, suggests that Central and Eastern Europe might be able to improve its ambient water quality substantially by considering the relative effects and pollution control costs of point sources of pollutant discharges into river basins, and to do so in a way that would be cheaper than adopting the minimum discharge and best-available technology policies of Western Europe and North America. The study of alternative water quality enhancement policies accounts for the location of each major point source of discharges into the Nitra River basin, which is located in a heavily industrialized area of the Slovak Republic; the pollution control costs of each of these sources; and the effects of each source's discharges on the basin's ambient water quality. It focuses on concentrations of dissolved oxygen, which are often used as a broad measure of the quality of water and the health of aquatic ecosystems, and it considers the effects of three types of policies to increase such concentrations. The first policy is to require point sources to increase the current concentration of dissolved oxy-



gen in the basin by reducing pollutant discharges to the lowest possible level using the best-available pollution control technologies. The second policy is for the region in which the Nitra River basin is located to implement what for it would be the least-cost strategy for increasing the concentration of dissolved oxygen in the basin to 4.0 milligrams per liter (mg/l), a concentration high enough to sustain fish and other forms of aquatic life. The third policy is for the region to implement what would be the least-cost strategy for increasing this concentration to 6.0 mg/l.

A comparison of the costs of each of these three policies reveals that the minimum discharge/best-available technologies (MD/BAT) policy is the most expensive (see table, p. 31). While this policy would increase the concentration of dissolved oxygen in the Nitra River basin to 6.9 mg/l, it would do so at an annual cost of approximately $14.4 million (U.S. dollars). In contrast, the annual cost of each of the least-cost policies is less than half this figure. The least-cost policy to increase the concentration of dissolved oxygen to 6.0 mg/l would entail an annual cost of $6.6 million; the least-cost policy to increase this concentration to 4.0 mg/l would entail an annual cost of only $2.8 million. Both least-cost policies represent a substantial improvement over maintenance of the status quo (the base case), even though the cost of the latter is zero. This is because the currently low concentration of dissolved oxygen in the basin—0.7 mg/l—is likely to be detrimental to many forms of aquatic life.

The above cost comparisons illustrate the likely ratio of cost savings that could be achieved through the use of a least-cost policy to increase concentrations of dissolved oxygen. The 4.0 mg/l concentration could be achieved at less than 20 percent of the cost of the MD/BAT policy, while the 6.0 mg/l concentration could be achieved at less than 50 percent of the cost of this policy. The question that arises is whether similar cost savings would be realized if least-cost pollution control policies were applied to river basins larger than the Nitra River basin. Given the magnitude of potential cleanup costs relative to GDP in Central and Eastern Europe, the answer to this question is doubtless of considerable interest to the region's governments.

Comparison of Base Case and Alternative Policies to Increase the Concentration of Dissolved Oxygen in the Nitra River Basin

Policy	Minimum concentration of dissolved oxygen (mg/l)	Annual cost (millions of U.S. dollars)	Percentage of cost of MD/BAT policy
Maintain status quo (base case)	0.7	0	not applicable
Minimum discharge/best-available technologies (MD/BAT)	6.9	14.4	100
Regional least-cost (4 mg/l)	4.0	2.8	19
Regional least-cost (6 mg/l)	6.0	6.6	46

Adoption of least-cost pollution control policies

Despite the fact that resource economists have been advocating their use for more than two decades, least-cost pollution control policies are the exception rather than the rule in practice. Although the United States has recently adopted one such policy—trading among electric power plants of permits to emit sulfur dioxide—it and many other countries in the West have traditionally made little attempt to design and implement pollution control policies that are efficient in the sense that they will lead to ambient standards being met at the lowest possible cost. There are many reasons why such policies are not promulgated more often. They include technical difficulties in projecting the economic and environmental effects of alternative policies, concerns about whether pollution control costs will be evenly distributed among pollution sources, and the lack of institutions to coordinate management of environmental resources.

Given that cost-effective pollution control policies are not the norm in the West, it might be expected that Central and Eastern European countries would be hesitant to adopt them. However, these countries' severe resource constraints and their institutional flexibility—the result of recent political transformations in the former Soviet bloc—tend to make such policies particularly attractive and potentially easier to implement than in the West. This combination of conditions suggests that Central and Eastern European governments may be more attuned to the arguments of resource economics than Western governments have been to date.

Charles M. Paulsen is a fellow in the Quality of the Environment Division at Resources for the Future. A more detailed account of the issues discussed in this article can be found in discussion paper QE93-21, "Cost-Effective Water Quality Management Strategies in Central and Eastern Europe," by Paulsen and László Somlyódy.

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