

**Impacts of Phase II SO₂
Emission Restrictions
on West Virginia's Economy**

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Executive Summary

West Virginia's economy is concentrated in energy-producing and energy-consuming sectors. The state's energy-intensive economy evolved in response to abundant supplies of comparatively low-cost energy — coal, natural gas, and electricity. Thus, the state and the welfare of its residents are particularly sensitive to events that change the behavior of energy markets.

There are presently several prospective changes in public policy that could have large effects on coal and electricity markets in West Virginia and nationally. A natural response to any of these recent or prospective policies is to ask, "What kind of impacts will this have in West Virginia's energy markets?" Furthermore, "With the state economy so dependent on energy-intensive industries, what could this policy do to broader measures of state economic activity, such as employment, GSP, personal incomes, or population?" This report addresses those questions for Phase II SO₂ restrictions under Title IV of the 1990 Clean Air Act Amendments. Companion reports examine the impacts on West Virginia's economy of EPA's NO_x SIP Call and of the Kyoto Protocol.

Phase II SO₂ Limits under Title IV of the Clean Air Act Amendments

Title IV of the 1990 Clean Air Act Amendments (CAAA) introduced controls on electric power plant emissions of SO₂ and NO_x in order to reduce the incidence of acid rain. For SO₂, the CAAA also introduced the innovation of nation-wide trading in SO₂ emission allowances. Each allowance gives a covered electric generating unit the right to emit one ton of SO₂. Utilities can use an allowance at the originally allocated generating unit, transfer it to another generating unit, sell it, or bank it for use in future years.

Title IV SO₂ controls are introduced in two phases. In Phase I, starting in January 1995, 261 "Table A" generating units in 110 plants were required to participate. These units received annual SO₂ emission allowances based on a rate of 2.5 lbs/mmBtu (pounds per million British thermal units) times their baseline annual heat input averaged from the 1985 - 1987 period. Nearly half of West Virginia's generating capacity including the Albright (Unit 3), Fort Martin, Harrison, Kammer, Mitchell, and Mt. Storm plants were required to participate in Phase I. Trading of allowances has been vigorous in Phase I. Allowance prices have been as low as \$66 at EPA's 1996 auction, but had increased to \$189 by early August of 1999. Many allowances have been banked for use under Phase II's more stringent limits.

Phase II begins in January of 2000 and tightens the standard SO₂ emission rate while expanding coverage broadly. Nearly every existing electric generating unit over 25 MW and all new units are required to participate. Allowance allocations will generally be based on 1.2 lbs/mmBtu times the 1985-1987 baseline. Under Phase II owners of electric generating units will have four options they can use to comply with Title IV's SO₂ requirements: 1) acquire and surrender allowances equal to the quantity of SO₂ emissions; 2) switch to fuels with lower sulfur content; 3) install flue gas desulfurization (scrubber) equipment; or 4) retire the plant.

Study Process

There are three basic elements that must be brought together in a specific logical sequence to produce the impact estimates. The first of these is a model of West Virginia's economy that consists of a mathematical representation of the relationships among different parts of the economy — household consumption, investment, production, employment, wages, prices, incomes, population migration, production costs, and so forth. This study uses the REMI model of West Virginia's economy. The second basic element is a baseline scenario that describes what West Virginia's economy would look like without the Phase II SO₂ limits. Running the baseline scenario through the REMI model creates a control forecast. The third basic element in the study process is a policy scenario describing the direct effects Phase II would have on West Virginia's economy. The study used three types of information to develop the Phase II SO₂ scenario and to translate that scenario into policy variables that can be inserted in a REMI simulation. These were: 1) energy industry statistical profiles, primarily from the U.S. Energy Information Administration; 2) prior studies of CAAA Title IV SO₂ limits and SO₂ emission allowance markets; and 3) advice from members of an Advisory Board convened for the study. The final stage in the study process was to use the REMI model to simulate an alternative forecast based on the Phase II scenario. Comparing the policy scenario forecast with the control forecast reveals the estimated economic impacts of Phase II SO₂ emission limits.

Economic impacts are changes in the level of activity or some other attribute (e.g., wage rates) of an economy that are attributable to some policy or event. Impacts are not the same as benefits or costs. In benefit-cost studies a benefit is the amount people would be willing to pay to make a specific event happen or to acquire a good or service. A cost is the amount people would be willing to pay to avoid occurrence of a specific event or to avoid giving up something of value. (This definition of cost is different from, but related to, the common definition of cost as what someone pays to acquire something.) An impact may be a benefit (lower food prices), a cost (increased incidence of illness requires greater expenditures on health care), or neither (employment shifts from one industry to another with no change in wage rates).

Direct Impact Scenario

The policy scenario of Phase II's direct impacts consists of several elements. First, the Mount Storm electric generating plant is installing a new flue gas desulfurization unit ("scrubber"). Second, the broader and more stringent SO₂ emission standards in Phase II may further change the balance between low-sulfur and high-sulfur coals in West Virginia and national markets. Third, the cost of producing coal-fired electricity will increase, either to operate and amortize the SO₂ scrubbers or to purchase SO₂ allowances to cover uncontrolled excess emissions. This in turn leads to the fourth direct impact — the price of electricity in West Virginia will increase, both in absolute terms and relative to national average prices.

The scenario for Phase II of Title IV SO₂ standards can be summarized with values for capital expenditures on scrubbers, the reduction in West Virginia coal sales, the price of SO₂ emission

allowances, and the increase in the price of electricity compared to baseline prices:

Capital Costs:	\$166 million
Change in West Virginia Coal Sales:	-5.0% to domestic, out-of-state markets
SO ₂ Emission Allowance Price:	\$90/ton Phase I baseline
	\$150/ton in 1998
	\$190/ton in 1999
	\$200/ton in 2000
	\$303/ton in 2010
	\$240/ton in 2020
Electricity Price Increase:	0.8 to 2.9 mills/kWh

There are several direct impacts of Phase II that are not included in this scenario because their likely magnitudes are small and/or the information available to quantify them is limited. These include lime purchases for scrubber operation, shifts in the mix of fuels used to generate electricity, utility windfalls from distribution of emission allowances, reductions in national electricity consumption due to higher prices, labor productivity gains brought about by improved health, and improvements in agricultural and forestry yields.

Since the Clean Air Act Amendments of 1990 are on the books and the regulations for Phase II of Title IV's SO₂ provisions are set, there is no uncertainty that the policy will be implemented starting in 2000. Nevertheless, there are some uncertainties pertaining to other environmental policies that may interact with the SO₂ provisions of Title IV, future prices of SO₂ emission allowances, and the market for West Virginia coal.

Economic Impacts of Phase II SO₂ Limits

Table ES below summarizes results from the study.

Table ES				
Economic Impacts of Phase II SO₂ Limits				
	2000	2005	2010	2020
Output (millions of 1992 \$)	-260	-341	-415	-464
GSP (millions of 1992 \$)	-170	-225	-273	-305
Employment	-2,200	-2,700	-3,000	-2,800
Annual Wage Rate (\$)	-28	-30	-18	8
Wages & Salaries (millions \$)	-70	-94	-109	-122
Per Capita Income (1992 \$)	-38	-18	-11	7
Population	-1,100	-4,300	-6,000	-6,600

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Introduction: West Virginia's Energy Intensive Economy

West Virginia's economy is concentrated in energy-producing and energy-consuming sectors. The state's energy-intensive economy evolved in response to abundant supplies of comparatively low-cost energy — coal, natural gas, and electricity. For example, in 1997 industrial customers in West Virginia paid an average of \$2.91 per thousand cubic feet for natural gas compared to \$3.59 nationally,¹ and in 1998 they paid an average of 3.8 ¢/kWh (cents per kilowatthour) for electricity compared to 4.5 ¢/kWh nationally.²

Table 1 illustrates the importance of energy to West Virginia's economy with data on employment, employee earnings, and gross state product (GSP) for selected industries in 1997. Coal mining, oil and gas extraction, natural gas distribution, and electricity are the state's major energy-producing industries. West Virginia sold 70.4% of its electricity generated in 1998 and 83.1% of its coal production in 1997 out-of-state.³ So in addition to being large, electricity and coal are important parts of the state's export base. The four manufacturing industries (out of twenty) in Table 1 each include sectors that spend over 5% of their revenues on electricity purchases. Primary aluminum spends 20.5%, cement 10.6%, carbon and graphite products 5.5%, and reconstituted wood products 5.5% of revenues on electricity.⁴ Combined, just the eight listed energy-intensive industries accounted for 9.7% of employment, 24.0% of employee earnings, and 27.1% of GSP in the entire state economy!

Because large parts of West Virginia's economy are based on abundant, low-cost energy, the state and the welfare of its residents are particularly sensitive to events that change the behavior of energy markets. There are presently several prospective changes in public policy that could have large effects on coal and electricity markets in West Virginia and nationally. Most, but not all, of these are proposed or pending environmental regulations. These prospective policy changes include: 1) the start in 2000 of Phase II of the 1990 Clean Air Act Amendments (CAAA) restrictions on SO₂ emissions to control acid rain; 2) the U.S. Environmental Protection Agency's (EPA) NO_x State Implementation Plan (SIP) Call, which would require the state to reduce NO_x emissions; 3) the Kyoto Protocol to limit emissions of greenhouse gases, notably CO₂; 4) additional restrictions on the scope of mountaintop removal coal mining and associated valley fills; 5) restructuring of electricity markets and the introduction of

¹U.S. Energy Information Administration, *Natural Gas Annual 1997*, October 1998, Table 27.

²U.S. Energy Information Administration, *Electric Power Annual 1998 Volume 1*, Table A15.

³Computed from data in U.S. Energy Information Administration, *Electric Power Annual 1998 Volume 1*, Tables A1 and A11 and *Coal Industry Annual 1997*, Tables 61 and 62.

⁴Minnesota IMPLAN Group, *1994 U.S. Structural Matrices*.

competition;⁵ and 6) rail competition leading to lower costs of transporting low-sulfur coal from Wyoming's Powder River Basin. A natural response to any of these recent or prospective policies is to ask, "What kind of impacts will this have in West Virginia's energy markets?" Furthermore, "With the state economy so dependent on energy-intensive industries, what could this policy do to broader measures of state economic activity, such as employment, GSP, personal incomes, or population?"

This report addresses those questions for Phase II SO₂ restrictions under Title IV of the CAAA. Companion reports examine the impacts on West Virginia's economy of EPA's NO_x SIP Call and of the Kyoto Protocol.⁶ The next section describes the Phase II SO₂ emission restrictions. The following section gives an overview of the process used in this study, including subsections describing the REMI model of West Virginia's economy, and discussing the nature and interpretation of impacts. The fourth section details the scenario used to describe the Phase II SO₂ limits' direct impacts and contains a subsection about potential alternatives to the selected scenario. The body of the report concludes with total (economy-wide) impact estimates for a variety of variables. An appendix covers some of the technical details encountered in developing the direct impact scenario.

Phase II SO₂ Limits under Title IV of the Clean Air Act Amendments

Title IV of the 1990 Clean Air Act Amendments (CAAA) introduced controls on electric power plant emissions of SO₂ and NO_x in order to reduce the incidence of acid rain. For SO₂, the CAAA also introduced the innovation of nation-wide trading in SO₂ emission allowances. Each allowance gives a covered electric generating unit the right to emit one ton of SO₂. Utilities can use an allowance at the originally allocated generating unit, transfer it to another generating unit, sell it, or bank it for use in future years. This creates a market for SO₂ emissions, rather than having the EPA control the actual emissions of each unit. Because generating units where SO₂ reductions are expensive can acquire allowances from units where the emission reductions are less costly, total SO₂ emissions can be reduced to the desired level at the least possible aggregate cost.

⁵For more on issues pertaining to electric industry restructuring in West Virginia, see West Virginia University, Electric Industry Restructuring Research Group, *Electric Industry Restructuring: Opportunities and Risks for West Virginia*, Reports 1-5, various dates July 1997 through September 1998.

⁶Greenstreet, David, *Impacts of Phase II SO₂ Emission Restrictions on West Virginia's Economy*, West Virginia University, Bureau of Business and Economic Research, December 1999 and Greenstreet, David, *Impacts of the Kyoto Protocol on West Virginia's Economy*, West Virginia University, Bureau of Business and Economic Research, December 1999.

Title IV SO₂ controls are introduced in two phases.⁷ In Phase I, starting in January 1995, 261 “Table A” generating units in 110 plants were required to participate. These units received annual SO₂ emission allowances based on a rate of 2.5 lbs/mmBtu (pounds per million British thermal units) times their baseline annual heat input averaged from the 1985-1987 period. The Table A units have at least 100 MW capacity and previously emitted SO₂ at a rate greater than 2.5 lbs/mmBtu. Table A incorporates nearly half of West Virginia’s generating capacity including the Albright (Unit 3), Fort Martin, Harrison, Kammer, Mitchell, and Mt. Storm plants.⁸ Phase I also covers units that opt in either as substitute sites for SO₂ reductions (167 units in 1995) or as units that compensate for reduced power generation at a Table A unit (7 units in 1995). In West Virginia, the Albright (Units 1 and 2), Pleasants, Rivesville, and Willow Island plants have opted in. Trading of allowances has been vigorous in Phase I. The CAAA requires the EPA to hold back 2.8% of allowances to conduct an annual auction, but several private exchanges have generated most of the trading volume. Allowance prices have been as low as \$66 at EPA’s 1996 auction, but had increased to \$189 by early August of 1999.⁹ Many allowances have been banked for use under Phase II’s more stringent limits. In 1995 the 435 Phase I units received 8.7 million tons of SO₂ allowances, but only emitted 5.3 million tons.¹⁰ In 1996 covered units received 8.1 million tons of allowances and emitted only 5.4 tons of SO₂.¹¹

Phase II begins in January of 2000 and tightens the standard SO₂ emission rate while expanding coverage broadly. Nearly every existing electric generating unit over 25 MW and all new units are required to participate, adding approximately 2,200 plants. Allowance allocations will generally be

⁷Useful summaries of the SO₂ provisions of Title IV appear in U.S. Energy Information Administration, *The Effects of Title IV of the Clean Air Act Amendments of 1990 on Electric Utilities: An Update*, March 1997 and in a symposium on SO₂ Trading in *Journal of Economic Perspectives*, 12(3), Summer 1998. The Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research, <http://web.mit.edu/ceepr/www/>, has produced many working papers on Title IV SO₂ trading and Resources for the Future, <http://www.rff.org/>, has also produced several discussion papers.

⁸U.S. Energy Information Administration, *The Effects of Title IV of the Clean Air Act Amendments of 1990 on Electric Utilities: An Update*, March 1997, Table B1.

⁹For more extensive discussion of allowance prices see the Uncertainties sub-section below.

¹⁰Ellerman, Denny A. et al, *Emissions Trading Under the U.S. Acid Rain Program: Evaluation of Compliance Costs and Allowance Market Performance*, Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research, 1997, page 10.

¹¹Ellerman, Denny A., Paul L. Joskow, and Richard Schmalensee, *1996 Update on Compliance and Emissions Trading under the U.S. Acid Rain Program*, Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research, page 2.

based on 1.2 lbs/mmBtu times the 1985-1987 baseline, although there are several complicating details. Because Phase II will cover all generating units, it will effectively cap SO₂ emissions at a level no greater than the sum of annual allocations and any remaining banked allocations from earlier years. The new emission allowances will total 9.4 million tons annually from 2000 through 2009 and 8.95 tons annually thereafter.¹²

Under Phase II owners of electric generating units will have four options they can use to comply with Title IV's SO₂ requirements: 1) acquire and surrender allowances equal to the quantity of SO₂ emissions; 2) switch to fuels with lower sulfur content; 3) install flue gas desulfurization (scrubber) equipment; or 4) retire the plant.¹³ Economic considerations will determine the mix of compliance options selected for each unit. Because allowances can be bought and sold, the opportunity cost of using allowances will equal their market price regardless of whether a unit uses more or fewer allowances than originally allocated.¹⁴ Switching fuels can involve blending, or entirely substituting, low-sulfur coal for higher-sulfur coal previously in use. Because for many power plants low-sulfur coal is more expensive, the difference in the cost of the low- and high-sulfur coal is a Title IV compliance cost. Another type of fuel switching replaces coal with natural gas, either completely or partially with cofiring.

Scrubbers inject an alkaline sorbent, usually lime or limestone, into the flue gas. The SO₂ reacts chemically with the sorbent leaving a solid by-product, usually gypsum, which is removed. Scrubbers are highly effective in removing SO₂ and a scrubbed power plant will invariably have more allocated emission allowances than it needs for its own operation. Wet scrubbers can reliably remove 95% of SO₂ and sometimes as much as 99%, while dry scrubbers can frequently remove more than 90%.¹⁵

¹²Ellerman, Denny A. *et al*, *Emissions Trading Under the U.S. Acid Rain Program: Evaluation of Compliance Costs and Allowance Market Performance*, Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research, 1997, page 9.

¹³Unlike Phase I, under Phase II opting in alternative substitution or compensating units is not applicable because all generating units are required to participate.

¹⁴An opportunity cost is the value of the best alternative use of a resource. If a unit needs extra allowances, they must be acquired at a cost determined by the market. If a unit has extra allowances, they can be sold to generate income or banked to be used or sold in a later period. (In practice, regulatory and tax constraints complicate this relationship between the market price of allowances and their value to generating unit owners.)

¹⁵U.S. Energy Information Administration, *The Effects of Title IV of the Clean Air Act Amendments of 1990 on Electric Utilities: An Update*, March 1997, page 10.

Study Process

Figure 1, provided by REMI, summarizes the process for estimating economic impacts used in this study. There are three basic elements that must be brought together in a specific logical sequence to produce the impact estimates. The first of these is a model of West Virginia's economy that consists of a mathematical representation of the relationships among different parts of the economy — household consumption, investment, production, employment, wages, prices, incomes, population migration, production costs, and so forth. This permits analysis of how a change in one part of the economy, an increase in electricity prices for example, propagates throughout the entire economy by way of these relationships. This study uses the REMI model of West Virginia's economy, as represented by the center box in Figure 1.¹⁶ The following subsection describes the structure of the REMI model in more detail.

The second basic element is a baseline scenario that describes what West Virginia's economy would look like without Phase II SO₂ restrictions. The upper right-side box in Figure 1 shows that this baseline scenario is described in terms of values of policy variables. Policy variables consist of the settings — equation parameters, initial values of economic variables, and forecasts of exogenous conditions in the national economy — that the REMI model uses as input in order to simulate an annual forecast of the state's economy. The control forecast represented in the lower right-side box is simulated from the baseline scenario's predicted values for policy variables. REMI comes with a default baseline scenario and control forecast extrapolated from current economic conditions without any changes in public policy or external factors.

For this study the baseline scenario and control forecast contain one change from the REMI default. Coal from Wyoming's Powder River Basin (PRB) is inexpensive to mine and low in sulfur, but has a high ash content and is remote from most markets. Due to improvements in rail transportation and fine-tuning of electric generating unit boilers, PRB coal is becoming increasingly competitive in Midwestern and even Eastern markets. At the same time, inflation-adjusted national coal mine revenues will be flat or decreasing. Even though tons of coal produced has increased at an annual average rate of 1.5% nationally between 1988 and 1997 (2.0% in West Virginia), falling prices mean that real (i.e. inflation-adjusted) revenues have decreased at an annual average rate of -3.6% (-1.6% in West Virginia).¹⁷ Furthermore, there are almost no announced plans for investments in new coal-fired electric generating units in spite of continued growth in the market for electricity.

¹⁶The specific version is REMI Policy Insight, WV State Model EDF5-53, Version 1.0 released September 1998, which is calibrated with historical data through 1996.

¹⁷Free on board adjusted to 1992 dollars using the implicit Gross Domestic Product deflator. Calculated from U.S. Energy Information Administration, *Coal Industry Annual 1997*, Tables 1 and 81.

Consequently, REMI's baseline forecast of 1.0% annual growth from 1996 to 2020 in West Virginia real coal revenues appears much too optimistic. Instead, the adjusted baseline forecast for this study assumes that real revenues from in-state and foreign coal shipments remain steady. Revenues from out-of-state domestic coal shipments are assumed to decrease from 1996 by 5% in 2000, 15% by 2010, and 20% by 2020. Since 1997 domestic out-of-state coal shipments were 60.75% of all coal shipments originating in West Virginia,¹⁸ this amounts to a decrease of 3.0% in real coal output by 2000, 9.1% by 2010, and 12.2% by 2020.

The third basic element in the study process is a policy scenario describing the direct effects that Phase II SO₂ restrictions would have on West Virginia's economy. This is the top box in Figure 1. The upper left-side box shows that this scenario has to be expressed in terms of the REMI model's policy variables. The study used three types of information to develop the Phase II SO₂ scenario and to translate that scenario into policy variables that can be inserted into a REMI simulation. These were: 1) energy industry statistical profiles, primarily from the U.S. Energy Information Administration; 2) prior studies of CAAA Title IV SO₂ limits and SO₂ emission allowance markets; and 3) advice from members of an Advisory Board convened for the study.

This study's Advisory Board consisted of 21 individuals with a background in some aspect of West Virginia's energy markets or environmental policy. The members had diverse backgrounds including state environmental and utility regulatory officials, representatives of the West Virginia Legislature and Governor's Office, electric utility staff, railroad coal market managers, representatives of mining and manufacturing trade associations, an engineering consultant, a private lawyer specializing in environmental issues, a union representative, members of environmental advocacy groups, and academics. Fifteen of the Advisory Board members attended an afternoon seminar that included a discussion of the Phase II SO₂ limits and the probable magnitudes of their direct impacts on the state economy. Several members provided specific information based on their professional knowledge and/or references to additional reports and sources of information. Each Advisory Board member received a draft copy of this report for review.¹⁹

The final stage in the study process, as represented by the lower left-side and bottom boxes in Figure 1, is to use the REMI model to simulate an alternative forecast based on the Phase II SO₂ scenario.

¹⁸Computed from U.S. Energy Information Administration, *Coal Industry Annual 1997*, Tables 58 and 61.

¹⁹Advisory Board members do not necessarily endorse the study's conclusions. While many of their comments were helpful, the author has sole responsibility for the final choices made in selecting the policy scenario and estimating economic impacts.

Comparing the scenario forecast with the control forecast reveals the estimated economic impacts of Phase II SO₂ limits. These impacts were estimated for each year through 2020 and cover all the various variables — household consumption, investment, production, employment, wages, prices, incomes, population migration, production costs, and so forth — forecast by the REMI model.

The REMI Model

REMI is an economic-demographic forecasting and simulation model with thousands of equations and policy variables. REMI is designed to forecast the impact of public policies and external events on the state's economy and population. As described in Figure 1 earlier in this section, any combination of the policy variables can be modified to simulate the economic and demographic impacts of a policy scenario. REMI includes blocks on: 1) output; 2) labor and capital demand; 3) population and labor supply; 4) wages, prices, and profits; and 5) market shares.

Figure 2 schematically represents the major variables in each of these blocks and the relationships among these variables. In Block 1, output in each of 53 sectors is determined by demand — consumption, investment, government spending, and exports — and local market shares. Block 2 shows that factor demands for labor and capital depend on outputs and the wage rate. The real wage rate and employment opportunities determine migration, and therefore population (by age and sex) and labor supply in Block 3. In the fourth block employment demand and labor supply determine employment opportunity and the wage rate. The wage rate, in turn, drives the real wage and production costs, which determine profitability and prices, which affect consumer prices, which loop back to the wage rate. In Block 5, local and export market shares depend on sectors' profitability and sales prices.

Interpreting Impacts

Economic impacts are changes in the level of activity or some other attribute (e.g., wage rates) of an economy that are attributable to some policy or event. Because an economy has many different characteristics — output, employment, wage rates, prices, incomes — any policy will have many different types of impacts. Regional economists distinguish between direct and total impacts. A direct impact is any change in an economy whose immediate cause is the policy or event in question. In this study direct impacts are represented as changes in the REMI policy variables, which make the policy scenario forecast differ from the control forecast. A total impact is the final change in a characteristic of the economy after all of the indirect influences work their way through the various components and markets of the economy. With REMI, these total impacts are equivalent to differences between the policy scenario and control forecasts.

Impacts are not the same as benefits or costs. In benefit-cost studies a benefit is the amount people would be willing to pay to make a specific event happen or to acquire a good or service. A cost is the amount people would be willing to pay to avoid occurrence of a specific event or to avoid giving up something of value. The terms “benefit” and “cost” are also applied to the specific event, good, or

service, itself.²⁰ Generally, benefits are based on either intrinsic value to a consumer (shoes, a car, more leisure, cleaner air), or resources saved in an existing activity so that the resources can then be used for something else (drivers' time saved because of a road improvement). Costs generally derive from something intrinsically undesirable (increased incidence of an illness), a reduction in something with value, or something that increases the resources required for an existing activity.

Public policies should generally be justified in terms of their benefits exceeding costs. The payments do not actually have to happen as long as individuals would be hypothetically willing to make them. Benefits and costs may or may not be tradable in markets. An impact may be a benefit (lower food prices), a cost (increased incidence of illness requires greater expenditures on health care), or neither (employment shifts from one industry to another with no change in wage rates). Even when an impact is associated with a benefit, their magnitudes need not be the same (a previously unemployed worker gains a job — the job pays a salary [an impact] but is not worth as much to the worker because she also loses leisure time).

This study addresses the potential economic impacts of Title IV Phase II SO₂ restrictions. It makes no attempt to assess the benefits or costs. In the case of Phase II, it happens that most of the costs, but not the benefits, are tradable and appear in economic markets (e.g., operating expenses for scrubbers or fuel switching) and are therefore observable as economic impacts. This does not mean the benefits are not real; just that they are not as closely associated with the impacts that can be modeled with the techniques used in this study. For example, a study by a team at Resources for the Future estimates that the health benefits of the SO₂ emission reductions under Title IV will be worth \$171.38 per person in West Virginia in 2010.²¹

Direct Impact Scenario

The reduced SO₂ emissions under Phase II of Title IV will have several direct impacts on West Virginia's economy. These direct impacts are quantified in the scenario described in this section. The scenario describes the incremental impacts of Phase II, that is, the alternative represented in the

²⁰To see the connection between an economist's definition of cost and the common definition, consider the example of an individual who pays a dollar (common definition of cost) to buy an ice cream cone on a hot day. Since a dollar is worth a dollar, the individual would be willing to pay up to a dollar (economist's definition of cost) in order to get the ice cream cone for "free" (i.e., to avoid giving up the dollar used to pay for the cone). The individual may have been willing to pay up to two dollars for the cone, making two dollars the benefit. If the individual had only been willing to pay up to fifty cents for the cone, the purchase would not be made.

²¹Burtraw, Dallas, et al, *The Costs and Benefits of Reducing Acid Rain*, Resources for the Future, Discussion Paper 97-31-REV, September 1997, page 19.

baseline scenario and control forecast is indefinite continuation of Phase I rules. This direct policy impact scenario can then be inserted into a REMI simulation in order to estimate the indirect and total impacts Phase II might have on the state's economy.

Scenario Elements

First, the Mount Storm electric generating plant is installing a new flue gas desulfurization unit ("scrubber"). Some of this investment is for on-site construction that creates local economic impacts. This is in addition to scrubbers installed, at the Harrison plant for example, for Phase I compliance.

Second, the broader and more stringent SO₂ emission standards in Phase II may further change the balance between low-sulfur and high-sulfur coals in West Virginia and national markets. West Virginia produces both low-sulfur and high-sulfur coal. However, coal from the Powder River Basin will gain market share because of its low sulfur content. On the other hand, more widespread adoption of scrubbing could reduce the importance of this effect.

Third, the cost of producing coal-fired electricity will increase compared to the baseline scenario, either to operate and amortize the SO₂ scrubbers or to purchase SO₂ allowances to cover uncontrolled excess emissions. This increase in electricity production costs will be greater in West Virginia than on average nationally because the state's electricity generation capacity is almost entirely coal-fired.

This in turn leads to the fourth direct impact; the price of electricity in West Virginia will increase, both in absolute terms and relative to national average prices. For businesses, especially electricity-intensive manufacturing industries, this means an increase in operating costs which will lead to some loss in competitiveness. For households, this means a higher cost of living that effectively reduces the value of real incomes.

The scenario for Phase II of Title IV SO₂ standards can be summarized with values for capital expenditures on scrubbers, the reduction in West Virginia coal sales, the price of SO₂ emission allowances, and the increase in the price of electricity compared to baseline prices:

Capital Costs:	\$166 million
Change in West Virginia Coal Sales:	-5.0% to domestic, out-of-state markets
SO ₂ Emission Allowance Price:	\$90/ton Phase I baseline
	\$150/ton in 1998
	\$190/ton in 1999
	\$200/ton in 2000
	\$303/ton in 2010
	\$240/ton in 2020
Electricity Price Increase:	0.8 to 2.9 mills/kWh

These translate into the following direct impacts entered into the REMI simulation:

Construction of Electric Utility Facilities:	\$25 million/year in 1999-2000
Change in West Virginia Coal Sales:	-2.9% starting in 2000
Public Utilities Production Costs:	+0.6% starting in 1998 increasing to +2.3% in 2010 then falling to +1.6% in 2020
Industrial Electricity Costs:	+1.1% starting in 1998 increasing to +3.9% in 2010 then falling to +2.7% in 2020
Commercial Electricity Costs:	+0.8% starting in 1998 increasing to +2.7% in 2010 then falling to +1.9% in 2020
Price of Household Operating Expenses:	+0.3% starting in 1998 increasing to +0.9% in 2010 then falling to +0.6% in 2020

The public utilities production costs as well as the industrial and commercial electricity costs are each expressed as changes in West Virginia relative to the nation. For example, if West Virginia industrial electricity prices increased 10% while national industrial electricity prices went up an average of 5%, the REMI industrial electricity price would go up approximately 5% ($\{[1.10/1.05]-1\} * 100$).

This scenario is based on a combination of industry statistics, forecasts of SO₂ emission allowance prices, and utility SO₂ control expenditure plans. Interested readers can find a description of the scenario's development in the appendix.

Elements Not Included

There are some additional potential direct effects of Title IV's Phase II SO₂ limits that are not considered in this report because their likely magnitude is small and/or the information available to quantify them is limited. Nevertheless, they should be noted for completeness. First, scrubber operation creates demand for inputs, particularly for sorbent based on limestone or lime. How much, if any, of the sorbent for Phase II scrubbers (i.e., Mount Storm) would come from in-state is unknown. Second, in principle the increased costs of producing electricity in coal-fired generating units could lead to a shift in fuel demand towards natural gas. In practice this is very unlikely because, on the one hand, most existing coal-fired generating units have low enough operating costs to be dispatched anyhow, and on the other hand, new coal-fired generating units are not competitive because of capital costs and uncertainties over other environmental restrictions (e.g., Kyoto Protocol).

Third, under competitive markets electric generators receive a windfall when emission allowances are allocated to them. This is true even for a utility that uses rather than sells its allowances, because competitive prices of electricity will reflect the opportunity cost of the allowance, no matter how acquired. This windfall does not apply under rate of return regulation, and shareholders who do benefit

from the windfall will be scattered across the country. Therefore, the income impacts in West Virginia will be small.

Fourth, the general increase in electricity prices will moderately reduce national consumption of electricity. Other forms of energy will replace electricity, industry and commerce will substitute other inputs for energy and energy-intensive inputs, and consumers will substitute away from electricity and energy-intensive purchases. There are two ways that changes in national electricity consumption can have a direct impact on West Virginia's economy — changes in exports of coal or electricity. Both of these are already accounted for in the scenario for other reasons. Coal exports are reduced because of competition from all other fuels, notably low-sulfur Powder River Basin Coal. The REMI model simulates a reduction in the state's out-of-state electricity sales in response to its increased relative cost of producing electricity. In addition, changes in West Virginia's electricity prices are part of the scenario modeled.

Finally, implementation of Phase II will reduce atmospheric SO₂ in West Virginia. Some of the benefits from the SO₂ reduction can lead to economic impacts.²² First, health of the state's labor force will improve.²³ This, in turn, is likely to improve productivity and, consequently, both employee earnings and business competitiveness. Second, reductions in atmospheric SO₂ would reduce the extent of damage to the state's agricultural crops and forests.²⁴ Thus, the output and productivity of West Virginia's agricultural and forest products sectors would improve. Unfortunately, while SO₂'s health effects and ability to damage crops are well documented, this study found no references that quantify the resulting economic impacts in West Virginia.

Uncertainties

Since the Clean Air Act Amendments of 1990 are on the books and the regulations for Phase II of Title

²²James Kotcon of the study Advisory Board deserves credit for drawing the author's attention to these impacts.

²³See Burtraw, Dallas, et al, *The Costs and Benefits of Reducing Acid Rain*, Resources for the Future Discussion Paper 97-31-REV, September 1997.

²⁴See for example Davis, Donald D. and John M. Skelly, "Growth Response of Four Species of Eastern Hardwood Seedlings Exposed to Ozone, Acidic Precipitation, and Sulfur Dioxide," *Journal of the Air & Waste Management Association*, March 1992, 42(3), pages 309-311; Grant, William B., "The Role of Air Pollution in the Decline and Excess Mortality of Oaks and Hickories in the Eastern U.S.," in W. E. Sharpe and J. R. Drohan, eds., *The Effects of Acidic Deposition on Pennsylvania's Forests*, Environmental Resources Research Institute, 1999; and Bellani, L. M., et al, "Effects of Simulated Acid Rain on Pollen Physiology and Ultrastructure in the Apple," *Environmental Pollution*, 1997, 95(3), pages 357-362.

IV's SO₂ provisions are set, there is no uncertainty that the policy will be implemented starting in 2000. Furthermore, construction for additional scrubbers is already under way and Phase I trading of SO₂ emission allowances, which can be banked for Phase II, has been going on for several years. Nevertheless, there are some uncertainties pertaining to other environmental policies that may interact with the SO₂ provisions of Title IV, future prices of SO₂ emission allowances, and the market for West Virginia coal.

EPA's proposed revisions to the National Ambient Air Quality Standards (NAAQS) includes restrictions on particles finer than 2.5 microns (PM 2.5).²⁵ SO₂ contributes to the formation of these fine particulates. In May the U.S. Court of Appeals for the District of Columbia Circuit threw out the proposed regulations based on the doctrine of non-delegation of Congressional legislative authority and an inadequately documented scientific rationale for the standards. It is unclear whether the PM 2.5 standard will be revived, and if so, how much its implementation would restrain SO₂ emissions independent of the Title IV regulations. Similarly, the EPA is considering standards on regional haze that could potentially lead to non-Title IV restrictions on SO₂ emissions.

Predicting the future price of SO₂ emission allowances is hazardous — so far the allowance market has been volatile and somewhat unpredictable. Early predictions of SO₂ emission allowance prices were as high as \$1,500, and through 1995 forecasts for the price in 2010 were generally over \$500 (1995 prices).²⁶ Before Phase I began in 1995, actual trades were observed for as much as \$300, but the EPA's legislatively mandated allowance auctions cleared for the then surprisingly low prices of \$157 in 1993 and \$159 in 1994.²⁷ Allowance prices continued to fall during the early stages of Phase I, bottoming out in early 1996 at the low \$70's in the open market²⁸ and \$66 in that year's EPA auction.²⁹

²⁵The standards are an annual mean average of 15 micrograms/cubic meter and a 24-hour 65 micrograms/cubic meter based on the 98th percentile reading averaged over three years. See U.S. Environmental Protection Agency, *Regulatory Impact Analyses for the Particulate Matter and Ozone National Ambient Air Quality Standards and Proposed Regional Haze Rule*, July 1997, page 3-2.

²⁶Bohi, Douglas R. and Dallas Burtraw, *SO₂ Allowance Trading: How Experience and Expectations Measure Up*, Resources for the Future Discussion Paper 97-24, February 1997, page 10; and Burtraw, Dallas, *Cost Savings, Market Performance, and Economic Benefits of the U. S. Acid Rain Program*, Resources for the Future Discussion Paper 98-28-REV, September 1998, page 3.

²⁷Bohi, Douglas R. and Dallas Burtraw, *SO₂ Allowance Trading: How Experience and Expectations Measure Up*, Resources for the Future Discussion Paper 97-24, February 1997, page 10.

²⁸Ellerman, A. Denny, *Electric Utility Response to Allowances: From Autarkic to Market-Based Compliance*, Center for Energy and Environmental Policy Research, Massachusetts Institute of

However, in 1998 the market price for allowances ranged from \$89 all the way up to \$215,³⁰ and on August 5, 1999 the price quoted on one of the main exchanges trading allowances was \$189.³¹ Recent (post Phase I) forecasts of allowance prices in 2000 range from the EIA's \$90 (1997 prices),³² through Tellus Institute's \$125-\$197 (1994 prices),³³ to ICF Kaiser's \$200.³⁴ Recent predictions for 2010 include EIA at \$293 (1997 prices), Tellus Institute at \$236-\$418 (1994 prices), a Resources for the Future discussion paper at \$291 (1995 prices) for marginal cost,³⁵ and EPRI at \$435-\$498 (1995 prices) for marginal cost.³⁶ Only the EIA has published allowance price estimates past 2010 — a decrease to \$130 in 2020 (1997 prices).

The Powder River Basin in Wyoming has the largest reserves of very low sulfur coal — 24.4 billion tons at less than 0.6 lbs/mmBtu — in the country. Much of this coal also happens to be inexpensive to mine.³⁷ Therefore, Powder River Basin coal has been gaining market share (30.0% of domestic

Technology, June 1998, page 6; LaCount, Robert and Todd A. Meyers, "NO_x and SO_x Allowance Markets Impact Coal Prices," *Coal Age*, June 1999; and ICF Kaiser as quoted in *Electricity Daily*, April 12, 1999.

²⁹Bohi, Douglas R. and Dallas Burtraw, *SO₂ Allowance Trading: How Experience and Expectations Measure Up*, Resources for the Future Discussion Paper 97-24, February 1997, page 10.

³⁰Tesoriero, Paul, "Practical Applications Using Options in SO₂ Emissions Trading," *The Emissions Trader*, February 1999, page 1.

³¹Cantor-Fitzgerald Environmental Brokerage Services, www.cantor.com/ebs/home.htm, August 25, 1999.

³²U.S. Energy Information Administration, *Annual Energy Outlook 1999*, December 1998, page 86.

³³Bernow, Stephen et al, *A Study of the Impacts of EPA Phase II SO₂ and NO_x Emissions Standards on Electrical Generation Facilities in the ECAR Region*, Tellus Institute, May 1996, page 14.

³⁴As quoted in *Electricity Daily*, April 12, 1999.

³⁵Carlson Curtis, et al, *Sulfur Dioxide Control by Electric Utilities: What are the Gains from Trade?*, Resources for the Future Discussion Paper 98-44, page 18.

³⁶White, K., *The New Environmental Drivers*, EPRI 1998 as quoted in Smith Anne E., Jeremy Platt, and A. Denny Ellerman, *The Costs of Reducing Utility SO₂ Emissions — Not as Low as You Might Think*, August 1998, page 11.

³⁷U.S. Energy Information Administration, *Coal Industry Annual 1997*, Table 105.

shipments in 1997, up from 23.8% in 1993³⁸), and the tighter SO₂ budgets of Phase II are likely to accelerate this trend. On the other hand, West Virginia actually has the second largest reserve of very low sulfur coal — 7.2 billion tons. There do not appear to be any published studies that examine how much, if at all, West Virginia coal will lose additional domestic utility market share because of Phase II's effects. The prevailing view of the project Advisory Board was that Phase II could affect the competition between West Virginia and Powder River Basin coal in out-of-state markets, but that in-state mines should be able to hold on to their share of coal sales to in-state electric generating plants. The 5.0% reduction in state coal sales to out-of-state domestic markets was selected as an illustrative impact magnitude. The actual change in state coal sales due to Phase II will depend on a variety of factors including utility decisions to use scrubbers or fuel switching, interactions with transportation costs from Wyoming east, and the impact of other policies — regarding mountaintop removal mining, for example — on West Virginia's supply of low-sulfur coal.

Economic Impacts of Phase II SO₂ Limits

Figures 3 through 9 and Tables 2 through 8 summarize the Phase II SO₂ limit's estimated economic impacts on output, gross state product (GSP), employment, wage rates, total wage and salary earnings, personal incomes, and population in West Virginia. The figures graph totals for both the baseline and Phase II SO₂ scenarios for each year from 1997 through 2020. The tables report results for the illustrative years of 1997, 2000, 2005, 2010, 2015, and 2020. The tables also include industry division detail except for personal income and population, which includes age cohort detail.

General Observations

Four general observations apply across the impacted variables:

- ! The timing of the impacts reflects the timing of the Phase II SO₂ scenario. Impacts begin in 1998, which is the first year that electricity prices in the policy scenario deviate from the baseline scenario. In 1999 and 2000 stimulus from installation of scrubbing equipment dampens, but does not overcome, the negative impacts from higher electricity prices. The negative impacts jump in 2000 as Phase II actually begins and reductions in coal output enter the policy scenario. The negative impacts continue to grow through 2010. After 2010 the economic impacts level out as the SO₂ emission allowance price peaks and then declines slightly by 2020.
- ! Growth in output, GSP, and especially employment shows a temporary slowdown in 1999. This is the result of a national slowdown — forecast annual GDP growth of 2.0% compared to an average annual rate of 2.6% over the 1996 to 2010 period.
- ! The magnitudes of the impacts are small compared to the overall size of the state's economy. In

³⁸Computed from U.S. Energy Information Administration, *Coal Industry Annual 1997*, Table 59.

Figures 6 (annual wage rate), 7 (wages and salaries), and 8 (per capita personal income), the Phase II SO₂ graph is indistinguishable from the graph of the control forecast. Even for output (-0.58% in 2011-2017), GSP (-0.60% in 2011-2017), population (-0.40% in 2014-2019), and employment (-0.34% in 2010 and 2011), the largest annual impacts are much less than one percent.³⁹

- ! West Virginia's economy would take a very long time to fully adjust to the impacts of the Phase II SO₂ emission limits. By 2020 most of the aggregate impacts have nearly stabilized, but the composition of those impacts is still evolving. Even though the direct impacts in the scenario actually moderate after 2010, output and GSP of mining as well as output, GSP, and employment in services still decrease between 2015 and 2020 at a rate at least half the rate they decrease between 2005 and 2010. There are two reasons that the economy responds so slowly. First, it takes time for market shares of the state's industries to change in response to the increase in production costs. It also takes considerable time for the labor supply to adjust by means of out-migration.

Output and GSP

Output (Figure 3 and Table 2) and GSP (Figure 4 and Table 3) are both measures of the value of production and behave in a similar fashion. The results are presented in 1992 dollars to remove the effect of inflation over the extended period of the impact simulation. Output is the sum of the value of goods and services produced by each business in the state. GSP is the value added by those businesses while producing those goods and services. Output includes the value of purchased intermediate inputs (parts, supplies, business services) that are embodied in a business' product or service. GSP excludes the value of those intermediate inputs and includes only the additional value that the business creates with its factors of production (labor, capital, land).

- ! The Phase II SO₂ emission limit's impacts on output and GSP start slowly in 1998 and 1999 and then jump in 2000. Most of this jump is attributable to impacts on mining. Mining accounts for 58.1% of the output impact and 61.2% of the GSP impact in 2000 and continues to experience more than half of these impacts for several years. The Phase II scenario affects mining in two ways. First, there is a direct loss of coal production due to increased competition from low-sulfur coal from other regions. Second, the demand for coal used in West Virginia power plants is reduced from the baseline scenario because the higher relative price of

³⁹Some care should be used in comparing one figure to another, because the scales on the vertical axes were selected to cover growth over the forecast period, and predicted growth of some variables is much more rapid than for others. For example, in Figure 5 the 50 thousand range of the scale is less than 10% of the initial (1997) level of employment, while in Figure 7 the \$30 billion range is nearly double the initial wages and salaries. In percentage terms the impact on wages and salaries in 2020 (-0.29%) is almost as large as the impact on employment (-0.32%), but it doesn't look that way if the scales are ignored.

electricity reduces in-state electricity consumption and electricity exports.

- ! Over time the transportation and public utilities division's output and GSP impacts become more significant. This is the sector that includes electricity. Output and GSP impacts on transportation and public utilities reach their maximum in 2017 when the output impact is - \$117.8 million (25.6% of total output impact) and the GSP impact is -\$71.4 million (23.6% of total GSP impact). Demand for West Virginia electricity falls for four reasons. The industry's own market shares fall due to the increase in production costs. Its in-state industrial and commercial customers' electricity consumption falls because the price increase reduces their market shares. Third, households' purchasing power goes down because electricity, and products made with electricity, push up the cost of living. Over time losses of population and personal income also reduce demand for the state's products.

Employment

Employment impacts (Figure 5 and Table 4) parallel output and GSP impacts because businesses employ workers in order to make their products.

- ! Employment impacts are spread more evenly among industry divisions than are the output and GSP impacts. In 2000, mining still has the largest impacts (796 jobs lost), but other sectors, especially services and retail trade, also experience substantial impacts. By 2020 the employment impacts are largest in services. In that year mining, retail trade, and government have very similar impact magnitudes. The employment impacts in transportation and public utilities never reach the large shares that they have with the output and GSP impacts. The reason employment impacts are spread more broadly is that the coal mining and electricity sectors are very capital-intensive, while some of the divisions affected by the general reduction in population and incomes (retail, services) are more labor-intensive.
- ! In percentage terms, the impacts on employment are smaller than the impacts on output — - 0.26% versus -0.43% in 2000, -0.34% versus -0.57% in 2010, and -0.32% versus -0.56% in 2020. Again, the variation in labor intensity across industry divisions partly explains this pattern. In addition, the labor market's initial reaction to cuts in employment is a reduction in the wage rate, which induces businesses to keep some of the employees that would otherwise be lost.

Wages

The annual wage rates in Figure 6 and Table 5 are expressed in current dollars per employee. Total wage and salary earnings (Figure 7 and Table 6) are also in current dollars for the entire West Virginia economy. Total wages and salaries is the product of employment and the annual wage rate, so its impacts depend on employment and wage rate impacts.

- ! The annual wage rate as well as total wages and salaries increase steadily in both the control and Phase II SO₂ scenarios. The annual wage rate starts at \$20,295 in 1997 and increases to over \$45,600 by 2020. Total wage and salary earnings grow from \$17.4 billion in 1997 to

\$41.2 billion (baseline scenario) or \$41.1 billion (Phase II scenario) in 2020.

- ! The annual wage rate impact is actually positive (\$2.35) in 1999 during the scrubber installation phase of the policy scenario due to the increase in demand for labor. Starting in 2000, as electricity prices continue to go up and as coal production drops, the impact on wage rates turns negative, reaching a maximum of -\$33.97 in 2002. After 2002 the wage rate impacts gradually shrink until they turn positive in 2018, reaching \$7.57 by 2020. This gradual movement from a negative to a positive impact on annual wage rates happens because labor supply is adjusting to reduced employment opportunities and the increased cost of living tends to push wage rates up.
- ! In 1999, the impact on total wages and salaries is also positive (\$2.0 million) since the wage rate increase more than makes up for the employment losses that year. After 2000 the impact on wages and salaries is negative because both the wage rate and employment impacts are negative. This negative impact on wage and salary earnings continues to grow through 2020 because the effect of expanding employment losses is larger than the effect of smaller wage rate reductions. However, the smaller wage rate impacts do slow the growth of the earnings impact in the later years.
- ! In the first years of the new decade impacts on wage rate, and especially wages and salaries, are largest in mining, responding to the reductions in coal production. By 2020 transportation and public utilities has the largest negative impact on wage rates and the second largest negative impact on earnings as demand for electricity drops due to higher costs and prices. By 2010 the wage rate impacts in most sectors are positive as higher living costs and adjusted labor supply dominate over reduced labor demand. However, wage rate impacts in transportation and public utilities, mining, and construction remain negative because the demand for employees falls more in the occupations predominant in those industries.

Income

Personal income and per capita income expressed in constant dollars (1992 prices) are useful measures of the population's financial well-being (Figure 8 and Table 7). Personal income impacts depend on the components of personal income, especially wages and salaries. Population changes also contribute to impacts on per capita income.

- ! The policy scenario's impacts on total personal income are negative throughout the forecast period, reaching a maximum of -\$167.5 million in 2016. The negative impact on per capita income starts falling right after the coal production shock in 2000 and actually turns positive in 2014. Reductions in population and labor force explain this divergence in the two trends.
- ! In the early years of the forecast, changes in wage and salary earnings explain almost all of the impact on total personal income (95.3% in 2000). Eventually, impacts on proprietors' income; dividends, interest, and rents; and transfer payments play a larger role, and earnings impacts are not quite as important (60.9% in 2020).
- ! Even though real per capita income and disposable (i.e., after-tax) per capita income grow in both the control and scenario forecasts, West Virginia's disposable per capita income falls

further behind national per capita income. In 1997 the state's disposable per capita income is 88.0% of the national average, but by 2020 it is only 81.5% in the control scenario forecasts.

Population

Births, deaths, aging, and migration determine changes in West Virginia's population (Figure 9 and Table 8).

- ! Population impacts accumulate over extended periods of time as a result of migration. The population impact moves quickly negative between 1999 (-315 persons) and 2005 (-4,280 persons). Then, as employment opportunities and wage rates stabilize, the population impact reaches a maximum of -6,779 in 2017 and moderates slightly by 2020.

Appendix: Computation of Scenario Values

There are three logically connected ways to approach the costs to electricity producers of complying with the Title IV Phase II SO₂ standards — one based on anticipated emission allowance prices, one based on the price differential between high-sulfur and low-sulfur coal, and one based on costs of installing and operating flue gas desulfurization equipment (scrubbers). Once those compliance costs are estimated, they can be used to calculate the impact on electricity prices using marginal costs in the case of competitive electricity markets or average costs if rate of return regulation still applies. From the start of Phase II in 2000 to the end of the forecast period in 2020, most parts of the market for electric generation will probably be competitive.⁴⁰

With unrestrained and competitive trading, the price of allowances should equal the anticipated costs of controlling a ton of SO₂ at the most expensive electric generating unit that chooses to install scrubbers or to rely on switching to lower sulfur coal. Units that would find it more expensive to install controls or switch fuel can save money by buying allowances; units that can control their SO₂ emissions for less than the going price of allowances face lower costs by installing the scrubbers or switching fuels than by buying allowances. When deciding whether to install scrubbers, the anticipated allowance price and premiums for low-sulfur coal would be compared to the total control cost per ton of SO₂, including amortizing the capital costs; once scrubbers are installed the choice to use them would depend only on the operating costs. The average total cost per ton of SO₂ controlled with scrubbers would always be less than the cost per ton at the most expensive unit scrubbing, and thus should also be less than the allowance price. System-wide, the market would drive up the price of allowances until units install scrubbers or substitute low-sulfur coal to meet the aggregate SO₂ emission budgets. Similarly, in the coal markets the price premium for low-sulfur coal will rise until the cost of the most expensive fuel-switching undertaken equals the alternative cost of buying allowances. If fuel-switching were more attractive at the margin than allowances, then the low-sulfur premium would rise and allowance prices fall until that point was reached.⁴¹

Similarly, under competition the price of electricity would equal the marginal cost of production, that is,

⁴⁰Several states, including Pennsylvania, Maryland, and Ohio, have already passed electric industry restructuring plans; the West Virginia Public Service Commission is presently conducting hearings on features of a West Virginia restructuring plan; FERC Orders 888 and 889 have already deregulated large parts of the electricity wholesale market; and both the Administration and key legislators have released proposals for federal legislation.

⁴¹The option of banking allowances for future years complicates the story, but does not invalidate the argument. Choices to use allowances in the current period or bank them will depend upon electricity producers' discount rate and the anticipated outcome in future years of the same set of trade-offs that Title IV compliance poses in the present year.

the incremental cost of producing the most expensive kWh used.⁴² Under Phase II the cost of producing that most expensive kWh will include some mix of costs for operating scrubbers, burning low-sulfur coal, and using allowances for the remaining SO₂ emitted. If the mix of scrubbing, low-sulfur coal, and allowances were efficient, then the cost of this mix should be the same as if allowances alone were used for this last increment of SO₂. Thus, the portion of an allowance consumed for that last SO₂ increment times the allowance price would be the amount added to the marginal cost of producing electricity.⁴³ Under competition this would also be the amount added to the price of electricity. With rate of return regulation, on the other hand, utilities are guaranteed a set rate of profit, and their averaged total operating costs are one component of their regulated electricity prices. In this case the average total costs of scrubbing and shifting to low-sulfur coal, adjusted for any allowances purchased/sold, would be added to the price of electricity. Mathematically, this average cost of SO₂ control cannot be greater than the marginal cost of SO₂ control that would be added to the competitive price of electricity.

With this reasoning in mind, it is possible to proceed with quantifying the direct impact scenario based on the predicted price of SO₂ emission allowances. The Uncertainties subsection in the body of this report lists some historical allowance prices and published estimates of future prices. The scenario allowance prices in 1998 and 1999 (\$150/ton and \$190/ton, respectively) are typical of prices actually observed, and the \$200/ton price in 2000 is consistent with ICF Kaiser's recent short-term forecast and actual prices in late summer of 1999. Projecting forward from 2000 is more difficult. The scenario selected is based on the allowance price changes from 2000 to 2010 and 2020 in EIA's *Annual Energy Outlook 1999*, but taking \$200/ton rather than \$90/ton as the starting point. This also works out as consistent with utility banking of allowances. A competitive market with observed allowance banking should lead to a pattern in which the price increases over time at the same rate as the discount rate of capital. If the price increases faster than this rate, a utility can make money from banking more allowances by purchasing them or controlling more SO₂ emissions. If the price increases slower than this rate, a utility can save money by using more allowances or selling them. Burtraw notes that an allowance price of "about \$95 in 1997" would be consistent with "long-run marginal costs of \$291 in 2010."⁴⁴ Since the allowance price in 1995 averaged roughly \$110,⁴⁵ this fits nicely with the 2010

⁴²There are complications involving long-run availability of generating capacity versus short-run consumption of energy that are ignored here.

⁴³Because demand for electricity responds to changes in the price, the incremental kWh without Phase II restrictions will not be the same as the incremental kWh under a scenario with those restrictions. Thus, calculating electricity price changes based on allowance prices is strictly an upper bound. However, the likely size of this demand elasticity effect is small compared to the other uncertainties already embodied in the scenario.

⁴⁴Burtraw, Dallas, *Cost Savings, Market Performance, and Economic Benefits of the U.S. Acid Rain Program*, Resources for the Future Discussion Paper 98-28- REV, September 1998, page 8. Smith, Anne E., Jeremy Platt, and A. Denny Ellerman, *The Costs of Reducing Utility SO₂*

scenario price of \$303.

Because the direct impact of Phase II depends on the change in SO₂ emission allowance prices, the scenario also requires an allowance price under the hypothetical alternative that Phase I continues indefinitely without the added restrictions of Phase II. The selected price of \$90 is typical of observed prices in 1996 and 1997, following the plunging prices and price expectations through early 1996 and before prices began rising substantially in anticipation of Phase II. As already mentioned, allowance banking indicates that even in 1996 and 1997 the prospect of Phase II was influencing the market for allowances. However, that prospect may well have encouraged additional scrubber investments on mandatory Phase I plants as well as more voluntary opt-in of plants in Phase I, both in order to generate extra allowances to bank for Phase II. Thus, a Phase I-only equilibrium price with little or no banking may not have been much different, because the supply of allowances would have been less if not for actions taken in anticipation of Phase II.

The next issue is to determine how much SO₂ would be emitted to produce the marginal kWh of electricity — that is, the amount that must be either scrubbed, reduced with low-sulfur coal, and/or paid for with emission allowances. Although the shift from Phase I to Phase II entails an aggregate shift in SO₂ allowances by tightening standards from 2.5 to 1.2 lbs/mmBtu and expanding the number of generating units covered, from the perspective of an individual unit the change takes the form of impacts on the allowance price and a reduced windfall from allowance allocations. The transition from Phase I to Phase II only changes the economics of a generating unit's compliance choices by changing the allowance price. The baseline amount of SO₂ (potentially) emitted in producing the marginal kWh, which must be scrubbed, reduced, or paid for with allowances, does not change.⁴⁶

Emissions — Not as Low as You Might Think, August 1998, page 16 makes the same point and arrives at a similar prediction (\$259 to \$302 in 2008 to 2010) for allowance prices.

⁴⁵Ellerman, A. Denny, *Electric Utility Response to Allowances: From Autarkic to Market-Based Compliance*, Center for Energy and Environmental Policy Research, Massachusetts Institute of Technology, June 1998, Figure 1.

⁴⁶Potentially, however, the price of coal with the baseline sulfur content, described in the next paragraph, could go down due to reduced demand under Phase II. If that were the case, the reduced cost of this coal would partially offset the price of emission allowances, thus reducing the marginal compliance cost based on an all-allowance strategy for the SO₂ produced with the marginal kWh of electricity. Whether, and how much, this baseline coal price change takes place depends on characteristics of the supply of baseline coal. This scenario assumes that the baseline coal supply is elastic so that no price change occurs in response to changes in the quantity demanded by electric power plants.

Because low-sulfur coal is an alternative to allowances with its own cost, the actual observed sulfur content of the coal consumed is not an appropriate point of reference for computing the cost per kWh of using allowances. On the other hand, the spectrum of sulfur content from high to low is a continuum rather than a discrete break. In addition, electric generating plants may have reasons other than Title IV — fuel supply economics and other environmental regulations — for using coal with less than the highest sulfur content. The scenario in this report is based on the pre-Title IV sulfur content status quo. In 1994, the last year before Phase I of Title IV went into effect, Phase I plants without scrubbers emitted an average of 2.82 lbs/mmBtu of SO₂.⁴⁷

With these assumptions, it is now possible to calculate Phase II's incremental impact on electricity production costs and price. First, convert the baseline sulfur emissions to mmBtu's per ton of SO₂ emitted:

$$2,000/2.82 = 709 \text{ mmBtu/ton SO}_2$$

To change units from mmBtu's to kWh's requires the average heat rate in the state's coal-fired electric generating units. In 1998 coal from West Virginia averaged 12,385Btu/lb, and the state's power plants generated 89,008 million kWh of electricity while burning 35,132 thousand tons of coal.⁴⁸ Thus the average heat rate is:

$$12,385*2,000/(35,132/89,008,000) = 9,777 \text{ Btu/kWh}$$

Then for every ton of SO₂ emitted with only baseline controls, West Virginia utilities can generate:

$$709*1,000,000/9,777 = 72,540 \text{ kWh/ton SO}_2$$

Finally, using the allowance price of \$303 (minus \$90 Phase I baseline) in 2010 as an example:

$$213*1,000/72,540 = 2.9 \text{ mills/kWh}$$

For comparison, EIA reports that operating costs, excluding capital, for scrubbers retrofitted under Phase I average 1.42 mills/kWh.⁴⁹ A report from Tellus Institute calculates an illustrative total cost, including amortizing capital, of retrofitted scrubbing of 8 mills/kWh.⁵⁰

Continuing with the scenario in 2010 as an example, to get from a 2.9 mills/kWh increase in the price of electricity to percentage increases in relative costs and prices for the REMI model, first note the

⁴⁷Carlson, Curtis et al, *Sulfur Dioxide Control by Electric Utilities: What are the Gains from Trade?*, Resources for the Future Discussion Paper 98-44, page 11.

⁴⁸U.S. Energy Information Administration, *Cost and Quality of Fuels for Electric Utility Plants 1998 Tables*, June 1999, Table ES3, and *Electric Power Annual 1998, Volume 1*, Tables A2 and A5.

⁴⁹U.S. Energy Information Administration, *The Effects of Title IV of the Clean Air Act Amendments of 1990 on Electric Utilities: An Update*, March 1997, page 11.

⁵⁰Bernow, Stephen, et al, *A Study of the Impacts of EPA Phase II SO₂ and NO_x Emissions Standards on Electrical Generation Facilities in the ECAR Region*, page 17.

average revenue per kWh sold in West Virginia in 1998:⁵¹

All Sectors:	5.1¢
Industrial:	3.8¢
Commercial:	5.5¢
Residential:	6.3¢

Next attribute half of the price and cost changes for electricity production, industrial electricity consumption, and commercial electricity consumption to changes relative to the national price. (Note that coal-fired generation accounted for 99.3% of electricity produced in West Virginia compared to 56.3% nationally in 1998.⁵²) Finally, electricity accounts for 80% of the public utility sector⁵³ and is assumed to account for 20% of household operating expenses. Then:

Public Utilities Production Costs:	$(0.29/5.1)*0.5*0.8 = 2.3\%$
Industrial Electricity Costs:	$(0.29/3.8)*0.5 = 3.9\%$
Commercial Electricity Costs:	$(0.29/5.5)*0.5 = 2.7\%$
Price of Household Operating Expenses:	$(0.29/6.3)*0.2 = 0.9\%$

Increases in utility construction for the scenario are straightforward. The Mount Storm plant is presently installing a scrubber at a total reported capital cost of approximately \$100/kW. With a coal-fired capacity of 1,662MW that works out to \$166.2 million. Cost engineering data⁵⁴ indicate that approximately 30% of this amount would go for on-site construction. The balance of capital costs consist of purchased components and controls, project engineering and management, and catalyst, which are likely to come from out-of-state. Allocating the construction expenditures over two years produces a figure of \$24.9 million per year.

⁵¹U.S. Energy Information Administration, *Electric Power Annual 1998, Volume 1*, Table A15.

⁵²U.S. Energy Information Administration, *Electric Power Annual 1998, Volume 1*, Tables A1 and A2.

⁵³Computed from value added data in IMPLAN data files for the 1996 U.S. input-output model.

⁵⁴Personal communication from William Pollock, AOI Consulting.

Table 1				
West Virginia Employment, Earnings & Gross State Product (GSP) of Selected Industries				
Industry	SIC	Employment	Earnings*	GSP*
		1997	1997	1997
West Virginia	-	864,305	17,355	38,228
Mining	-	28,843	1,492	3,154
Coal mining	12	20,289	1,284	2,886
Oil and gas extraction	13	7,457	168	204
Manufacturing	-	85,875	3,337	6,684
Lumber and wood products	24	12,171	290	447
Stone, clay, and glass products	32	6,432	196	341
Primary metal industries	33	11,861	637	827
Chemicals and allied products	29	15,114	991	3,065
Transportation and public utilities	-	45,135	1,682	4,672
Electric, gas, and sanitary services	49	10,782	597	2,605

Source: U.S. Department of Commerce, Bureau of Economic Analysis, *State Personal Income 1929-1997*, and *Gross Product by Industry for U.S. and States, 1977-97*, CD-ROMs.

*Note: Earnings and GSP expressed in millions of current dollars.

Table 2
Industry Output Impact of Phase II SO₂

Total Output	1997	2000	2005	2010	2015	2020
Baseline Forecast	58,541	61,109	66,990	72,331	77,747	82,619
SO ₂ Policy Forecast	58,541	60,849	66,649	71,916	77,296	82,155
Difference	0	-260	-341	-415	-451	-464
Differences by Division	1997	2000	2005	2010	2015	2020
Mining	0	-151	-169	-184	-194	-203
Construction	0	-10	-29	-29	-25	-20
Durable Manufacturing	0	-6	-7	-13	-19	-22
Nondurable Manufacturing	0	-5	-7	-12	-16	-18
Transportation & Public Utilities	0	-38	-69	-104	-117	-116
Finance, Insurance, & Real Estate	0	-11	-12	-14	-15	-15
Retail	0	-15	-17	-21	-22	-22
Wholesale	0	-10	-12	-14	-15	-15
Services	0	-15	-18	-25	-30	-35
Agriculture, Forestry, & Fishing	0	0	0	0	0	0

Note: Industry Output measured in millions of 1992 dollars.

Table 3
Gross State Product Impact of Phase II SO₂

Gross State Product	1997	2000	2005	2010	2015	2020
Baseline Forecast	37,628	39,342	43,074	46,272	49,467	52,354
SO ₂ Policy Forecast	37,628	39,172	42,849	45,999	49,170	52,049
Difference	0	-170	-225	-273	-297	-305
Differences by Division	1997	2000	2005	2010	2015	2020
Mining	0	-104	-117	-126	-134	-140
Construction	0	-5	-14	-14	-12	-10
Durable Manufacturing	0	-2	-3	-5	-7	-8
Nondurable Manufacturing	0	-2	-3	-5	-7	-8
Transportation & Public Utilities	0	-22	-41	-63	-71	-70
Finance, Insurance, & Real Estate	0	-7	-8	-10	-10	-10
Retail	0	-9	-11	-14	-14	-14
Wholesale	0	-7	-8	-10	-11	-10
Services	0	-9	-11	-15	-18	-21
Agriculture, Forestry, & Fishing	0	0	0	0	0	0
Government	0	-2	-8	-12	-13	-13
Farm	0	0	0	0	0	0

Note: GSP measured in millions of 1992 dollars.

Table 4
Employment Impact of Phase II SO₂

Total Employment	1997	2000	2005	2010	2015	2020
Baseline Forecast	845,701	851,324	869,950	875,142	879,245	877,169
SO ₂ Policy Forecast	845,701	849,133	867,288	872,169	876,307	874,385
Difference	0	-2,191	-2,662	-2,973	-2,938	-2,784
Differences by Division	1997	2000	2005	2010	2015	2020
Mining	0	-796	-648	-565	-492	-424
Construction	0	-129	-355	-339	-273	-210
Durable Manufacturing	0	-50	-39	-51	-56	-55
Nondurable Manufacturing	0	-22	-24	-34	-39	-40
Transportation & Public Utilities	0	-156	-227	-303	-310	-287
Finance, Insurance, & Real Estate	0	-63	-73	-85	-88	-88
Retail	0	-383	-417	-464	-444	-412
Wholesale	0	-86	-95	-105	-101	-92
Services	0	-424	-486	-615	-675	-729
Agriculture, Forestry, & Fishing	0	-14	-16	-19	-21	-21
Government	0	-69	-283	-395	-440	-427
Farm	0	0	0	0	0	0

Table 5
Annual Wage Rate Impact of Phase II SO₂

Annual Wage Rate	1997	2000	2005	2010	2015	2020
Baseline Forecast	20,295	22,460	26,083	31,539	38,013	45,618
SO ₂ Policy Forecast	20,295	22,432	26,053	31,521	38,007	45,626
Difference	0	-28	-30	-18	-6	8
Differences by Division	1997	2000	2005	2010	2015	2020
Mining	0	-32	-81	-69	-52	-5
Construction	0	-10	-38	-39	-30	-14
Durable Manufacturing	0	-6	-17	3	29	58
Nondurable Manufacturing	0	-10	-22	9	49	92
Transportation & Public Utilities	0	-27	-64	-82	-83	-70
Finance, Insurance, & Real Estate	0	-2	-4	10	25	40
Retail	0	-2	-3	7	18	30
Wholesale	0	-6	-11	13	42	71
Services	0	2	9	26	37	44
Agriculture, Forestry, & Fishing	0	-2	-2	7	17	26

Note: Annual Wage Rate measured in current dollars.

Table 6
Total Wages & Salaries Impact of Phase II SO₂

Total Wages & Salaries	1997	2000	2005	2010	2015	2020
Baseline Forecast	17,444	19,502	23,230	28,328	34,375	41,233
SO ₂ Policy Forecast	17,444	19,432	23,136	28,219	34,257	41,111
Difference	0	-70	-94	-109	-118	-122
Differences by Division	1997	2000	2005	2010	2015	2020
Mining	0	-36	-35	-36	-36	-37
Construction	0	-3	-10	-12	-11	-10
Durable Manufacturing	0	-2	-2	-2	-2	-1
Nondurable Manufacturing	0	-1	-2	-2	-2	-1
Transportation & Public Utilities	0	-7	-12	-19	-23	-24
Finance, Insurance, & Real Estate	0	-1	-2	-2	-2	-2
Retail	0	-5	-7	-7	-7	-6
Wholesale	0	-3	-4	-4	-4	-4
Services	0	-8	-9	-10	-12	-17
Agriculture, Forestry, & Fishing	0	0	0	0	0	0

Note: Wages and Salaries measured in millions of current dollars.

Table 7
Personal Income Impact of Phase II SO₂

Total Personal Income	1997	2000	2005	2010	2015	2020
Baseline Forecast	34,951	36,499	38,420	40,464	42,567	44,630
SO ₂ Policy Forecast	34,951	36,410	38,294	40,302	42,399	44,467
Difference	0	-89	-126	-162	-168	-163
Per Capita Personal Income	1997	2000	2005	2010	2015	2020
Baseline Forecast	19,337	20,754	22,596	24,183	25,408	26,375
SO ₂ Policy Forecast	19,337	20,716	22,578	24,172	25,410	26,382
Difference	0	-38	-18	-11	2	7

Note: Total Personal Income measured in millions of 1992 dollars; Per Capita Income measured in 1992 dollars.

Table 8
Total Population Impact of Phase II SO₂

Total Population	1997	2000	2005	2010	2015	2020
Baseline Forecast	1,807,534	1,758,653	1,700,328	1,673,274	1,675,324	1,692,146
SO ₂ Policy Forecast	1,807,534	1,757,598	1,696,048	1,667,306	1,668,589	1,685,515
Difference	0	-1,055	-4,280	-5,968	-6,735	-6,631
Differences by Sex & Age	1997	2000	2005	2010	2015	2020
Male						
0 -14	0	-186	-757	-1,000	-942	-727
15 -24	0	-110	-379	-480	-626	-694
25 -64	0	-242	-995	-1,437	-1,682	-1,713
65+	0	-1	-19	-54	-98	-144
Female						
0 -14	0	-176	-716	-960	-909	-704
15 -24	0	-123	-405	-479	-602	-662
25 -64	0	-216	-989	-1495	-1773	-1829
65+	0	-1	-21	-60	-109	-153

Figure 1

Computing Impacts of a Policy

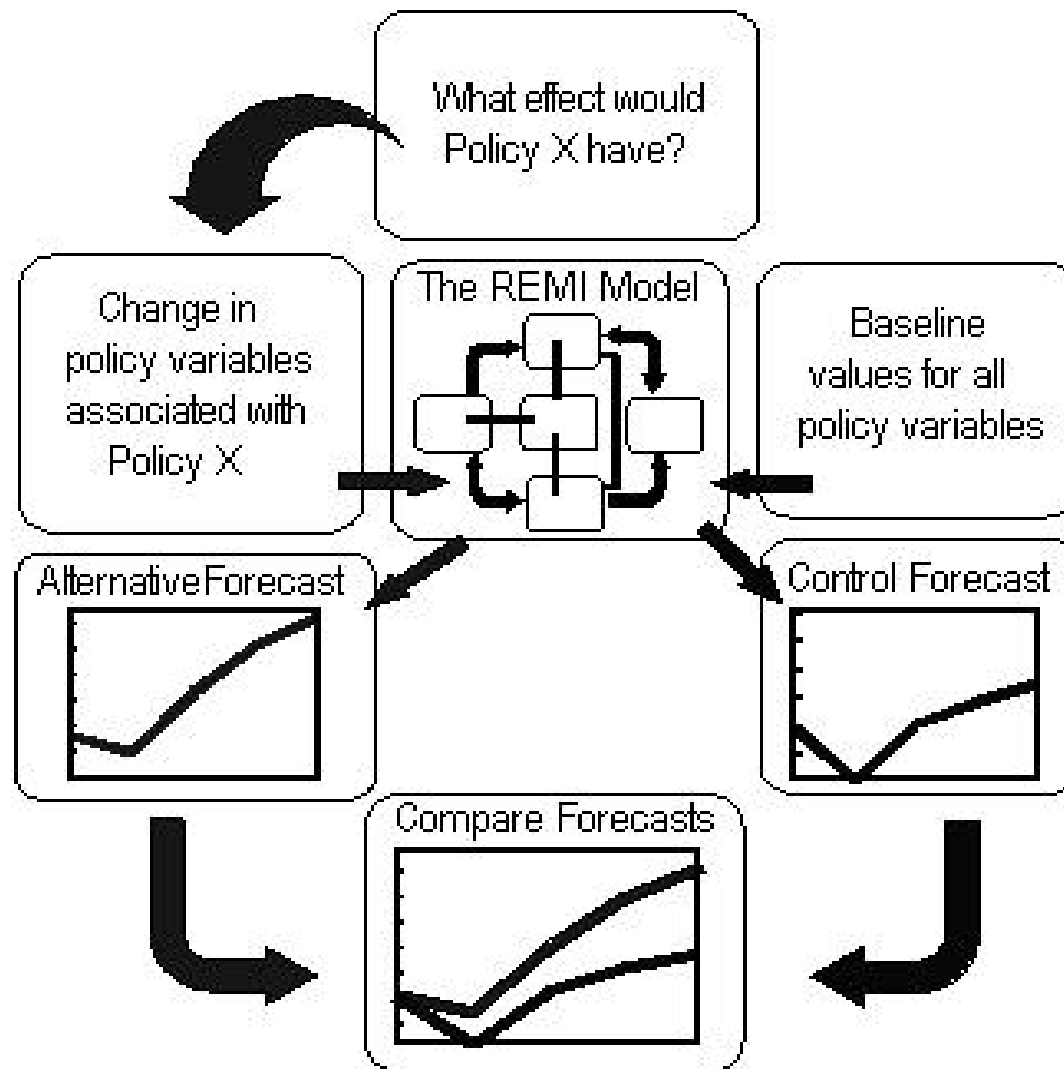


Figure 2 REMI Model Structure

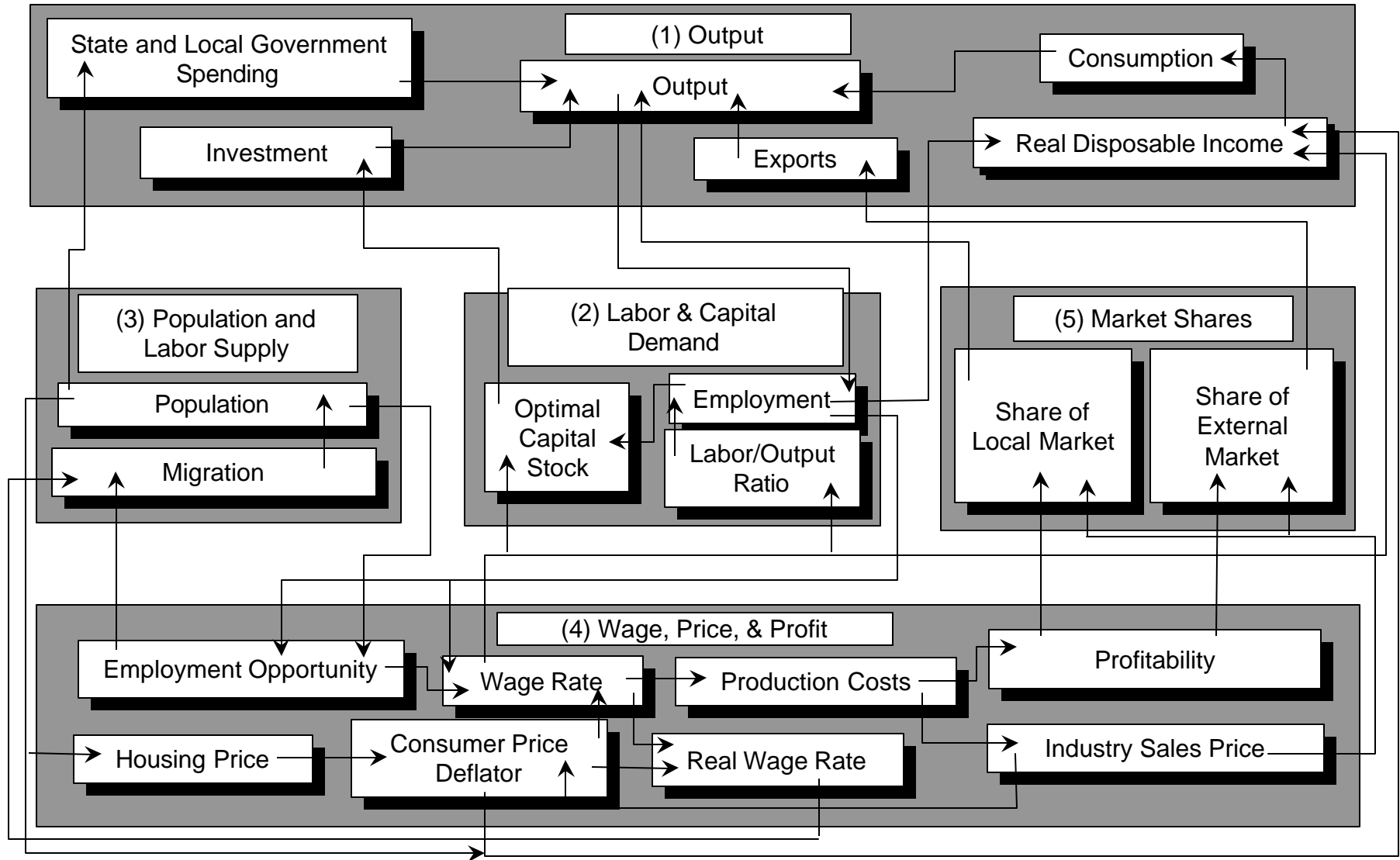


Figure 3
Phase II SO₂: Industry Output

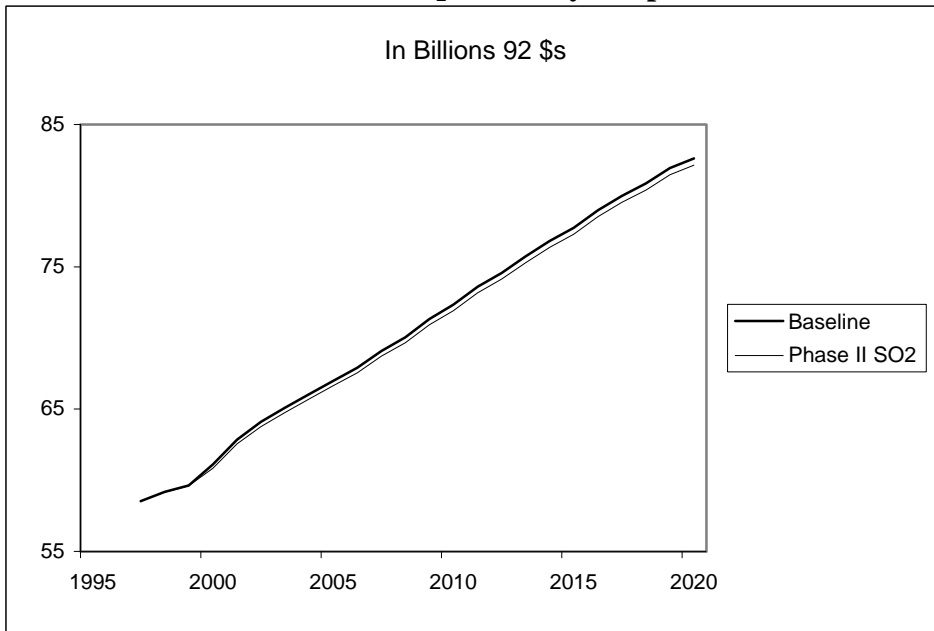


Figure 4
Phase II SO₂: Gross State Product

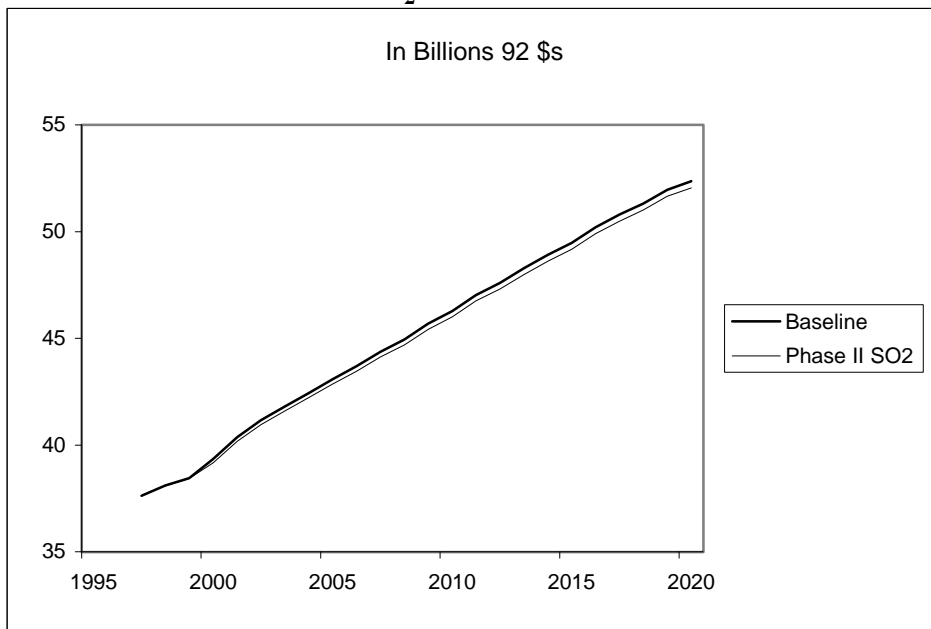


Figure 5
Phase II SO₂: Total Employment

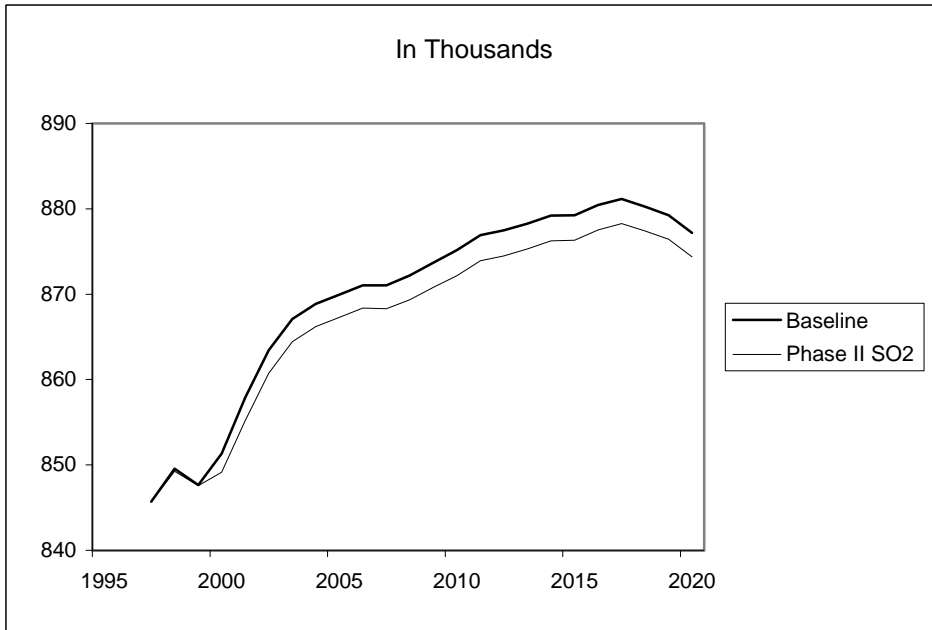


Figure 6
Phase II SO₂: Annual Wage Rate

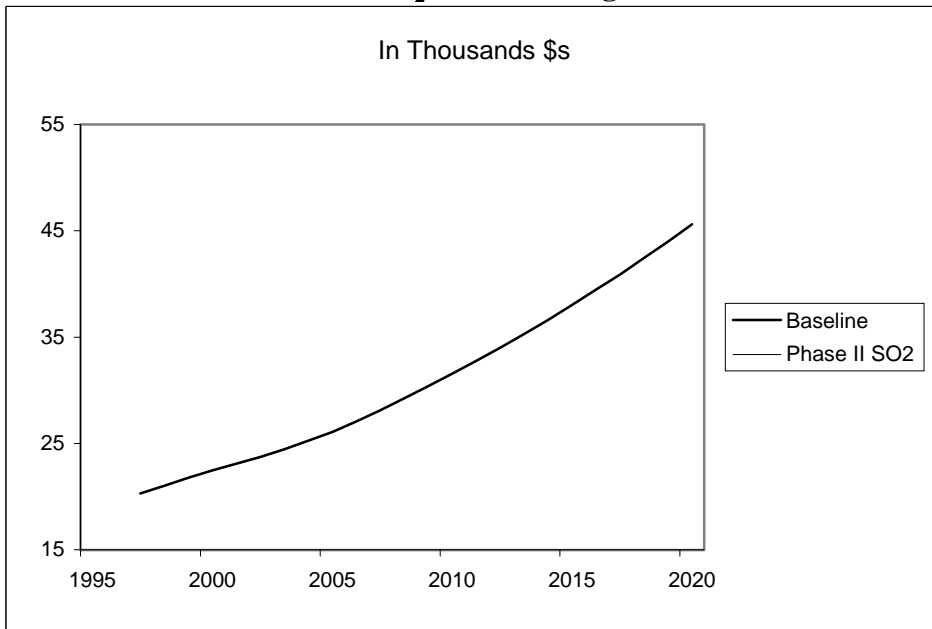


Figure 7
Phase II SO₂: Wages and Salaries

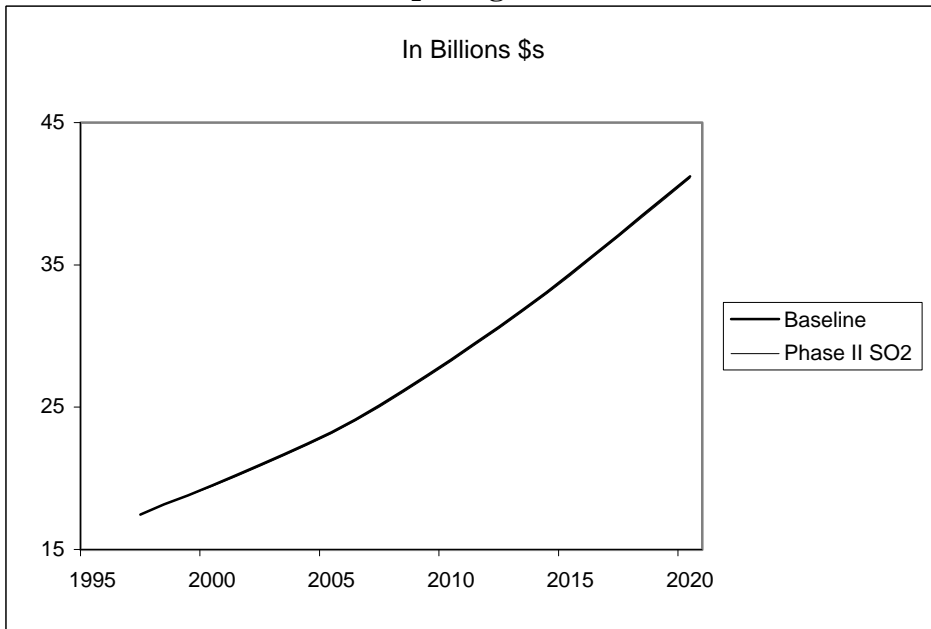


Figure 8
Phase II SO₂: Per Capita Personal Income

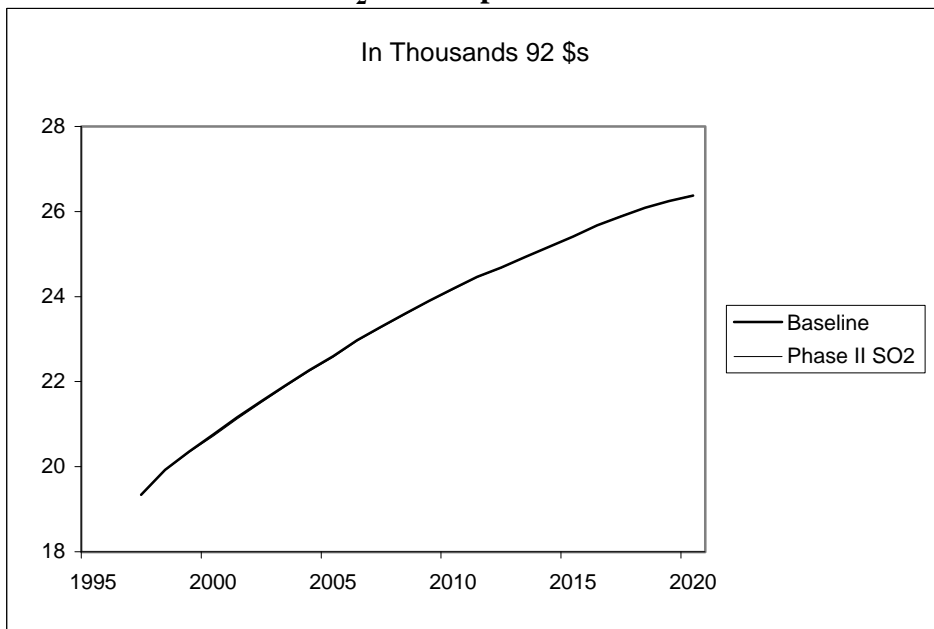


Figure 9
Phase II SO₂: Total Population

