Appendix 5b: Economic Impact of Modeled Controls

5b.1 Synopsis

This appendix presents the economic impact results of the illustrative modeled control strategy. Given the possible impacts of ozone precursor control measures on manufacturing industries, the transportation sector, electricity generators, consumers, and U.S. Gross Domestic Product (GDP) as a whole, we believe it is important to gauge the extent to which other parts of the economy might also be affected by implementing an alternate primary ozone standard. Therefore, an analysis of the economy-wide effects of implementing the alternate standard is conducted by inputting estimated direct engineering costs to EPA's computable general equilibrium model (Economic Model for Policy Analysis, or EMPAX-CGE).

Before the appendix commences with a background and description of EMPAX-CGE followed by a presentation of the results, three points are highlighted below that will assist the reader in interpreting the economic impacts and relating these impacts to the modeled control strategy engineering costs presented in Chapter 5.

(a) The selection criteria for the modeled control strategy, and its related compliance costs, is designed to select the least cost controls, from an engineering cost standpoint, that generate the greatest ozone reductions, but not necessarily the lowest economic impact. Therefore, although the control strategy is selected to reduce ozone at the lowest engineering cost, it does not necessarily represent the lowest impact strategy from an economic impact standpoint. Thus, while this economic impact analysis presents results for the modeled control strategy approach detailed in Chapter 3 of the RIA, it should not be viewed as reflecting the approach with the smallest economic impact. Instead, the results should be viewed as guidance or useful information for states preparing their implementation plans. It is likely that states will design implementation plans that apply alternative control strategies and in some cases design plans that take into account secondary impacts to industries and consumers within their boundaries. In such a case, the end result would be a set of State Implementation Plans (SIPs) that could be more economically optimal and may have lower impacts than those described below.

(b) The costs analyzed in this economic impact appendix include only the modeled engineering costs detailed in Chapter 5 for the alternate primary ozone standard. Thus, the economic impacts presented in this appendix reflect only the modeled engineering costs. Not included in estimating these economic impacts are the extrapolated cost estimates detailed in Chapter 5. This is because the extrapolated cost estimates are not available by industry, a necessary input to the operation of EMPAX. Therefore, the engineering costs for the illustrative modeled control strategy that are input to EMPAX in this analysis are those that reflect the $2.8 billion (2006 dollars) in 2020 for the application of known controls.

(c) In the interest of learning how possible changes in manufactured-goods prices might affect businesses and households, along with how changes in electricity/energy prices might affect industry groups that are large energy users, EPA employed the "EMPAX-CGE" computable general equilibrium (CGE) model, which has been peer reviewed and used in recent analyses of the Clean Air Interstate Rule (CAIR), the Clean Air Visibility Rule (CAVR), and the $PM_{2.5}$ NAAQS. As with similar models, EMPAX-CGE focuses on the cost-side of spillover effects on the economy. This implies its estimated industry-sector impacts may be overstated because EMPAX-CGE is not configured to capture the beneficial economic consequences of the increased labor availability and productivity expected to result from air quality improvements. EPA continues to investigate the feasibility of incorporating labor productivity gains and other beneficial effects of air quality improvements in CGE models and will incorporate labor productivity gains and other effects of air quality model improvements within future versions of EMPAX-CGE as is feasible.

EMPAX-CGE may also be used to generate the social costs associated with a regulation. The social costs associated with a regulation are those costs that result from the reaction of consumers and producers to the direct engineering costs of a regulation. The welfare of consumers and producers may be affected positively or negatively depending on the nature of the regulation, and this welfare change is a measure of the social costs. Such a welfare change could result from higher prices on output, which may lead to less demand by consumers and less output by producers. These changes due to the higher output prices are estimated as part of social costs. We apply the equivalent variation (EV) approach to estimate social costs using EMPAX-CGE in this RIA. This the first application of EV to estimate social costs as part of analysis using a CGE model in an RIA of this type. We explain how the EV approach can be used to estimate social costs, and why it is a better approach to estimating social cost than one using GDP in section 5b.4.4 of this appendix . Given a substantial number of caveats on results generated by EMPAX-CGE, we include social cost and do not compare these costs to the monetized benefits estimates provided later in this RIA. We also intend to solicit review and the advice of the SAB before we use this approach to estimate social costs before conducting any future economic impact analyses using CGE models.

5b.2 Background

To complement the analysis of effects on specific manufacturing sectors from AirControlNET 4.1, implications for mobile sources from MOBILE 6.2, NMIM, and NONROAD, and changes in electricity generation from IPM, the macroeconomic implications of the modeled control strategy have been estimated using EPA's EMPAX-CGE model. The focus of this component of the Ozone RIA is on examining the sectoral and regional distribution of economic effects across the U.S. economy. This section briefly discusses the EMPAX model and the approach used to incorporate findings from other models in EMPAX-CGE.

5b.2.1 Background and Summary of EMPAX-CGE Model

EMPAX was first developed in 2000 to support economic analysis of EPA's maximum achievable control technology (MACT) rules for combustion sources (reciprocating internal combustion engines, boilers, and turbines). The initial framework consisted of a national multimarket partial-equilibrium model with linkages only between manufacturing industries and the energy sector. Modified versions of EMPAX were subsequently used to analyze economic impacts of strategies for improving air quality in the Southern Appalachian mountain region as part of efforts associated with the Southern Appalachian Mountain Initiative (SAMI).

Recent work on EMPAX has extended its scope to cover all aspects of the U.S. economy at a regional level in either static or dynamic modes. Although major regulations directly affect a large number of industries, substantial indirect impacts may also result from changes in production, input use, income, and household consumption patterns. Consequently, EMPAX now includes economic linkages among all industrial and energy sectors as well as households that supply factors of production such as labor and purchase goods (i.e., a CGE framework). This gives the version of EMPAX called EMPAX-CGE the ability to trace economic impacts as they are transmitted throughout the economy and allows it to provide critical insights to policy makers evaluating the magnitude and distribution of costs associated with environmental policies. The dynamic version of EMPAX-CGE employed n this analysis, and its data sources, are described later on in Section 5b.3. EMPAX-CGE underwent peer review in 2006, and the results of that peer review can be found on the EPA Web site.[1] We have incorporated a number of recommendations offered in the peer review, including updating the energy production and consumption data (from DOE) to allow for more up to date characterization of energy markets and revising the uncompensated labor supply elasticities used in the model.

5b.2.2 EMPAX Modeling Methodology for the Modeled Control Strategy

EMPAX-CGE can be used to analyze a wide array of policy issues and is capable of estimating how a change in a single part (or multiple parts) of the economy will influence producers and consumers across the United States. However, some types of policies, including the Ozone National Ambient Air Quality Standard, are difficult to capture adequately within a CGE structure because of the boiler- and firm-specific nature of emission reduction costs. Consequently, an interface has been developed that allows linkages between EMPAX-CGE and the detailed technology models discussed in Chapter 5 (AirControlNET 4.1, MOBILE6.2, NMIM, and IPM 3.0). These linkages give the combined modeling system the advantages of technology detail and broad macroeconomic coverage, thereby permitting EMPAX-CGE to investigate economy-wide policy implications.

The technology models mentioned above estimate engineering cost changes by industry and region of the United States for the sectors of the economy affected by the alternate primary ozone standard. In order for EMPAX-CGE to effectively incorporate these additional costs, they have to be expressed in terms of the productive inputs used in CGE models (i.e., capital, labor, and material inputs produced by other industries). Rather than assume the costs represent a proportional scaling up of all inputs, Nestor and Pasurka (1995) data on purchases made by industries for environmental-protection reasons are used to allocate these additional expenditures across inputs within EMPAX-CGE. Once these expenditures are specified, the incremental engineering costs from the technology models can be used to adjust the production technologies in the CGE model. Also, for the modeled control strategy, linkages are made between EMPAX-

[1] http://www.epa.gov/ttn/ecas/models/empax_peer_review_comments_responses.pdf.

CGE and IPM to handle specific IPM findings related to resource costs and fuel consumption in electricity generation.[2]

5b.3 EMPAX-CGE Model Description: General Model Structure

This section provides additional details on the EMPAX-CGE model structure, data sources, and assumptions. The version of EMPAX-CGE used in this analysis is a dynamic, intertemporally optimizing model that solves in five year intervals from 2005 to 2050. It uses the classical Arrow- Debreu general equilibrium framework wherein households maximize utility subject to budget constraints, and firms maximize profits subject to technology constraints. The model structure, in which agents are assumed to have perfect foresight and maximize utility across all time periods, allows agents to modify behavior in anticipation of future policy changes, unlike dynamic recursive models that assume agents do not react until a policy has been implemented.

Nested CES functions are used to portray substitution possibilities available to producers and consumers. Figure 5b.1 illustrates this general framework and gives a broad characterization of the model.[3] Along with the underlying data, these nesting structures and associated substitution elasticities determine the effects that will be estimated for policies. These nesting structures and elasticities used in EMPAX-CGE are generally based on the Emissions Prediction and Policy Analysis (EPPA) Model developed at the Massachusetts Institute of Technology (Paltsev et al., 2005). This updated version of the EPPA model incorporates some extensions over the EPPA version documented in Babiker et al. (2001) such as specification of transportation purchases by households. These updates to transportation choices have been incorporated in this version of EMPAX-CGE as shown on the left-hand side of Figure 5b.1. Although the two models continue to have different focuses (EPPA is a model focused on analysis of national-level climate change policies while EMPAX is a model focused on regional-level analysis of pollution control policies), both are intended to simulate how agents will respond to environmental policies and as such EPPA provides a strong basis to develop the theoretical structure of EMPAX-CGE.

Given this basic similarity, EMPAX-CGE has adopted a comparable structure. EMPAX-CGE is programmed in the GAMS[4] language (Generalized Algebraic Modeling System) and solved as a mixed complementarity problem (MCP)[5] using MPSGE software (Mathematical Programming

[2] See Appendix E in the RIA for the Final CAIR rule for additional discussion of these IPM-EMPAX linkages (http://www.epa.gov/interstateairquality/technical.html).

[3] Although it is not illustrated in Figure 6.1, some differences across industries exist in their handling of energy inputs. In addition, the agriculture and fossil-fuel sectors in EMPAX-CGE contain equations that account for the presence of fixed inputs to production (land and fossil-fuel resources, respectively).

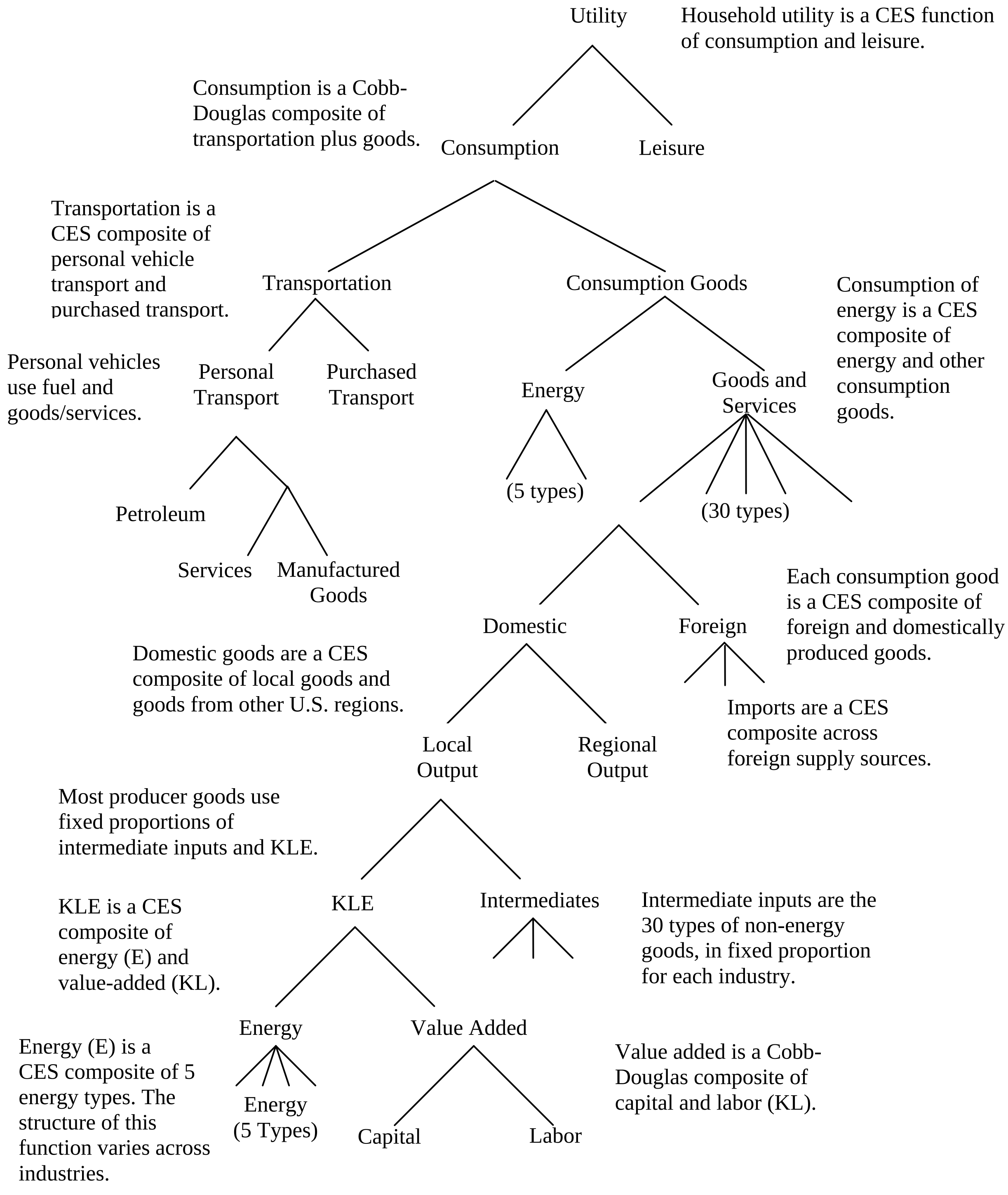
[4] See Brooke, Kendrick, and Meeraus (1996) for a description of GAMS (http://www.gams.com/).

[5] Solving EMPAX-CGE as a MCP problem implies that complementary slackness is a feature of the equilibrium solution. In other words, any firm in operation will earn zero economic profits and any unprofitable firms will cease operations. Similarly, for any commodity with a positive price, supply will equal demand, or conversely any good in excess supply will have a zero price.

Subsystem for General Equilibrium).[6] The PATH solver from GAMS is used to solve the MCP equations generated by MPSGE.

[6] See Rutherford (1999) for MPSGE documentation (http://www.mpsge.org/).

Figure 5b.1: General Production and Consumption Nesting Structure in EMPAX-CGE



5b.3.1 Data Sources

The economic data come from state level information provided by the Minnesota IMPLAN Group[7] and energy data come from EIA.[8] Forecasts for economic growth are taken from EIA's *Annual Energy Outlook 2007* (AEO) and Global Insight.[9] Although IMPLAN data contain information on the value of energy production and consumption in dollars, these data are replaced with EIA data since the policies being investigated by EMPAX-CGE typically focus on energy markets, making it essential to include the best possible characterization of these markets in the model. Although the IMPLAN data are developed from a variety of government data sources at the U.S. Bureau of Economic Analysis and U.S. Bureau of Labor Statistics, these data do not always agree with energy information collected by EIA directly from manufacturers and electric utilities.

EMPAX-CGE combines these economic and energy data to create a balanced social accounting matrix (SAM) that provides a baseline characterization of the economy. The SAM contains data on the value of output in each sector, payments for factors of production and intermediate inputs by each sector, household income and consumption, government purchases, investment, and trade flows. A balanced SAM for the year 2005 consistent with the desired sectoral and regional aggregation is produced using procedures developed by Babiker and Rutherford (1997) and described in Rutherford and Paltsev (2000). This methodology relies on optimization techniques to maintain the calculated energy statistics (in both quantity and value terms) while minimizing any changes needed in the other economic data to create a new balanced SAM based on EIA/IMPLAN data for the baseline model year (in essence, industry production functions are adjusted, if necessary, to account for discrepancies between EIA energy data and IMPLAN economic data by matching the energy data and adjusting the use of non-energy inputs so that the industry is in balance, i.e., the value of inputs to production equals the value of output).

These data are used to define economic conditions in 50 states within the United States (plus the District of Columbia), each of which contains 80 industries. Prior to solving EMPAX-CGE, the states and industries are aggregated up to the categories to be included in the analysis. Aggregated regions have been selected to capture important differences across the country in electricity generation technologies, while industry aggregations are controlled by available energy consumption data.

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[7] See http://www.implan.com/index.html for a description of the Minnesota IMPLAN Group and its data.

[8] These EIA sources include *AEO 2007*, the *Manufacturing Energy Consumption Survey*, *State Energy Data Report*, *State Energy Price and Expenditure Report*, and various annual industry profiles.

[9] See http://www.globalinsight.com/ProductsServices/ProductDetail1100.htm for a description of the Global Insight U.S. State Forecasting Service.

Table 5b.1 presents the 35 industry categories included in EMPAX-CGE for policy analysis. Their focus is on maintaining as much detail in the energy intensive and manufacturing sectors[10] as is

Table 5b.1: Industries in Dynamic EMPAX-CGE

EMPAX Industry	NAICS Classifications
Energy	
Coal	2121
Crude Oil[a]	211111, 4861
Electricity (*fossil and nonfossil*)	2211
Natural Gas	211112, 2212, 4862
Petroleum Refining[c]	324, 48691
General	
Agriculture	11
Mining (w/o coal, crude, gas)	21
Construction	23
Manufacturing	
Food Products	311
Textiles and Apparel	313, 314, 315, 316
Lumber	321
Paper and Allied	322
Printing	323
Chemicals	325
Plastic & Rubber	326
Glass	3272
Cement	3273
Other Minerals	3271, 3274, 3279
Iron and Steel	3311, 3312
Aluminum	3313
Other Primary Metals	3314, 3316
Fabricated Metal Products	332
Manufacturing Equipment	333
Computers & Communication Equipment	334
Electronic Equipment	335
Transportation Equipment	336
Miscellaneous remaining	312, 337, 339
Services	
Wholesale & Retail Trade	42, 44, 45
Transportation[b]	481-488
Information	51
Finance & Real Estate	52, 54
Business/Professional	53, 55, 56
Education (w/public)	61
Health Care (w/public)	62
Other Services	71, 72, 81, 92

[a] Although NAICS 211111 covers crude oil and gas extraction, the gas component of this sector is moved to the natural gas industry.

[b] The petroleum refining industry provided oil in delivered terms, which includes pipeline transport.

[c] Transportation does not include NAICS 4862 (natural gas distribution), which is part of the natural gas industry.

[10] Energy-intensive industry categories are based on EIA definitions of energy-intensive manufacturers in the *Assumptions for the Annual Energy Outlook 2007*.

allowed by available energy consumption data and computational limits of dynamic CGE models. In addition, the electricity industry is separated into fossil fuel generation and nonfossil generation, which is necessary because many electricity policies affect only fossil fired electricity.

Figure 5b.2 shows the five regions included in EMPAX-CGE in this analysis, which have been defined based on the expected regional distribution of policy impacts, availability of economic and energy data, and computational limits on model size. These regions have been constructed from the underlying state-level database designed to follow, as closely as possible, the electricity market regions defined by the North American Electric Reliability Council (NERC).[11]

Figure 5b.2: Regions Defined in Dynamic EMPAX-CGE

5b.3.2 Production Functions

All productive markets are assumed to be perfectly competitive and have production technologies that exhibit constant returns to scale, except for the agriculture and natural resource extracting sectors, which have decreasing returns to scale because they use factors in fixed supply (land and fossil fuels, respectively). The electricity industry is separated into two distinct sectors: fossil fuel generation and nonfossil generation. This allows tracking of variables such as heat rates for fossil fired utilities (Btus of energy input per kilowatt hour of electricity output).

[11] Economic data and information on nonelectricity energy markets are generally available only at the state level, which necessitates an approximation of the NERC regions that follows state boundaries.

All markets, must clear (i.e., supply must equal demand in every sector) in every period, and the income of each agent in the model must equal their factor endowments plus any net transfers. Markets in EMPAX clear in the 5 regions included in the dynamic model. Along with the underlying data, the nesting structures shown in Figure 5b-1 and associated substitution elasticities define current production technologies and possible alternatives.

5b.3.3 Utility Functions

Each region in the dynamic version of EMPAX-CGE contains four representative households, classified by income, that maximize intertemporal utility over all time periods in the model subject to budget constraints, where the income groups are:

- $0 to $14,999,
- $15,000 to $29,999,
- $30,000 to $49,999, and
- $50,000 and above.[12]

The percentage of U.S. households in each of these household classes is: 13% - $0 to $14,999; 18% - $15,000 to $29,999, 20% - $30,000 to $49,999, and 49% - $50,000 and above.[13] These representative households are endowed with factors of production including labor, capital, natural resources, and land inputs to agricultural production. Factor prices are equal to the marginal revenue received by firms from employing an additional unit of labor or capital. The value of factors owned by each representative household depends on factor use implied by production within each region. Income from sales of these productive factors is allocated to purchases of consumption goods to maximize welfare.

Within each time period, intratemporal utility received by a household is formed from consumption of goods and leisure. All consumption goods are combined using a Cobb Douglas structure to form an aggregate consumption good. This composite good is then combined with leisure time to produce household utility. The elasticity of substitution between consumption goods and leisure depends on empirical estimates of labor supply elasticities and indicates how willing households are to trade off leisure time for consumption. Over time, households consider the discounted present value of utility received from all periods' consumption of goods and leisure.

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[12] Computational limitations on EMPAX-CGE limit the number of household classes to four, and this is due to the complex modeling needed for the dynamic version of the model. We intend to review and potentially increase the number of household classes in future version of EMPAX-CGE, and will better reflect higher income household classes as part of that effort.

[13] U.S. Census Bureau, Current Population Survey, 2007 Annual Social and Economic Supplement. HINC-01. Selected Characteristics of Households, by Total Money Income. Found on the Internet at (http://pubdb3.census.gov/macro/032007/hhinc/new01_001.htm)

Following standard conventions of CGE models, factors of production are assumed to be intersectorally mobile within regions, but migration of productive factors is not allowed across regions. This assumption is necessary to calculate welfare changes for the representative household located in each region in EMPAX-CGE. EMPAX-CGE also assumes that ownership of natural resources and capital embodied in nonfossil electricity generation is spread across the United States through capital markets.

5b.3.4 Trade

In EMPAX-CGE, all goods and services are assumed to be composite, differentiated "Armington" goods made up of locally manufactured commodities and imported goods. Output of local industries is initially separated into output destined for local consumption by producers or households and output destined for export. This local output is then combined with goods from other regions in the United States using Armington trade elasticities that indicate agents make relatively little distinction between output from firms located within their region and output from firms in other regions within the United States. Finally, the domestic composite goods are aggregated with imports from foreign sources using lower trade elasticities to capture the fact that foreign imports are more differentiated from domestic output than are imports from other regional suppliers in the United States.

5b.3.5 Tax Rates and Distortions

Taxes and associated distortions in economic behavior have been included in EMPAX-CGE because theoretical and empirical literature found that taxes can substantially alter estimated policy costs (e.g., Bovenberg and Goulder [1996]; Goulder and Williams [2003]). For example, existing labor taxes distort economic choices because they encourage people to work below the levels they would choose in an economy without labor taxes and reduces economic efficiency[14]. When environmental policies raise production costs for firms and the price of goods and services, people may choose to work even less; the additional economic costs from this decision has been described as the "tax interaction" effect.

EMPAX-CGE considers these interaction effects by utilizing tax data from several sources and by explicitly modeling household labor supply decisions. The IMPLAN economic database provides information on taxes such as indirect business taxes (all sales and excise taxes) and social security taxes. However, since IMPLAN reports factor payments for labor and capital at their gross of tax values, we use additional data sources to determine personal income and capital tax rates. Information from the TAXSIM model at the National Bureau of Economic Research (Feenberg and Coutts, 1993), along with user cost of capital calculations from Fullerton and Rogers (1993), are used to establish tax rates. Elasticity parameters describing labor supply choice ultimately determine how distortionary existing taxes are in the CGE model. EMPAX-CGE currently uses elasticities based on the relevant literature (i.e., 0.4 for the compensated labor supply elasticity and 0.15 for the uncompensated labor supply elasticity). These elasticity

[14] These efficiency losses are often expressed in terms of overall marginal excess burden; the cost associated with raising an additional dollar of tax revenue. Estimates range from $0.10 to $0.35 per dollar (Ballard et al., 1985).

values give an overall marginal excess burden associated with the existing tax structure of approximately 0.3.

5b.3.6 Intertemporal Dynamics and Economic Growth

There are four sources of economic growth in EMPAX-CGE: technological change from improvements in energy efficiency, growth in the available labor supply (from both population growth and changes in labor productivity), increases in stocks of natural resources, and capital accumulation. Energy consumption per unit of output tends to decline over time because of improvements in production technologies and energy conservation. These changes in energy use per unit of output are modeled as AEEIs (Autonomous Energy Efficiency Improvements), which are used to replicate energy consumption forecasts by industry and fuel from EIA.[15] The AEEI values provide the means for matching expected trends in energy consumption that have been taken from the AEO forecasts. They alter the amount of energy needed to produce a given quantity of output by incorporating improvements in energy efficiency and conservation. Labor force and regional economic growth, electricity generation, changes in available natural resources, and resource prices are also based on the AEO forecasts.

Savings provide the basis for capital formation and are motivated through people’s expectations about future needs for capital. Savings and investment decisions made by households determine aggregate capital stocks in EMPAX-CGE. The IMPLAN dataset provides details on the types of goods and services used to produce the investment goods underlying each region’s capital stocks. Adjustment dynamics associated with formation of capital are controlled by using quadratic adjustment costs experienced when installing new capital, which imply that real costs are experienced to build and install new capital equipment.

Prior to investigating policy scenarios, it is necessary to establish a baseline path for the economy that incorporates economic growth and technology changes that are expected to occur in the absence of the policy actions. Beginning from the initial balanced SAM dataset, the model is calibrated to replicate forecasts from the AEO 2007. Upon incorporating these forecasts, EMPAX-CGE is solved to generate a baseline based on them through 2030. Once this baseline is established, it is possible to run the “counterfactual” policy experiments discussed below.

5b.3.7 Caveats Regarding EMPAX Modeling and the Results of this Analysis

The results generated by EMPAX-CGE that are provided in this RIA appendix, which include estimates of price and output changes by industry and energy impacts, have a number of caveats and limitations associated with them that one should be cognizant of. They are as follows:

As mentioned above, the current EMPAX-CGE model only considers the costs of policies and ignores the beneficial economic consequences of air quality improvements such as increased labor availability and productivity. If these health-related improvements were included in the model, any production decreases estimated by the model might be partially offset.

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[15] See Babiker et al. (2001) for a discussion of how this methodology was used in the EPPA model (EPPA assumes that AEEI parameters are the same across all industries in a country, while AEEI values in EMPAX-CGE are industry specific).

The extent of these potential benefits, along with current estimates of GDP impacts, depend on the labor supply elasticities in the model that have been chosen from the CGE literature on labor markets and tax distortions as discussed above. More flexible labor supply elasticities would allow additional response in labor markets to policy impacts, potentially with both positive and negative effects. Other critical assumptions in EMPAX-CGE largely revolve around the production technologies and input substitution options, which are based on the MIT EPPA model.

It is also highly uncertain as to which industries will be affected in the future when moving beyond where known engineering controls can currently apply. This mix of industries affected may be different than those current controls apply to, and tighter ozone standards may lead to consideration of controls to industries previously unaffected by measures related to ozone implementation. Ozone SIPs sometimes provide a "black box" (as per Section 182(e)(5) of the Clean Air Act) for additional controls to be supplied by unknown measures, and individual sectors where these controls may apply are never specified.[16]

EMPAX requires identification of costs by industry (by NAICS or SIC code) in order to operate. The capability of EMPAX to generate impacts is thus dependent on the extent to which the input costs by industry are defined. With a lack of knowledge of affected industries, there is also a lack of knowledge of affected consumers or households (thus, no way to estimate completely household welfare impacts).

Results from EMPAX are strongly influenced by elements in its baseline data set such as energy production and consumption data taken from the Energy Information Administration's Annual Energy Outlook (AEO). The current EMPAX version uses such energy data taken from the latest AEO version available (2007). This version of the AEO does not incorporate effects on energy production and consumption data associated with provision of the Energy Independence and Security Act of 2007 (or EISA) signed by the President on December 19, 2007.[17] Such effects include increased biofuels production, increased vehicle fuel efficiency, and new minimum energy efficiency standards for many electric appliances and products. The effects of EISA will be incorporated in a revised version of the AEO that will be released to the public in March, 2008.[18]

EMPAX keeps the location of labor constant in response to a supply shock. Hence, labor is not allowed to migrate between regions based on changes in wage rates. By not allowing labor migration, some inaccuracies in estimated changes in labor and wage rates may take place. These inaccuracies in estimated labor and wage rate changes may offset the inclusion of other

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[16] Section 182 (e) (5) of the Clean Air Act allows estimation of reductions (or so-called "black box" measures) in ozone SIPs that are not allocated by source category or sectors. An example of this is on pp. 6-12 and 6-13 in the 2003 California Air Quality Management Plan for Ozone and PM found at http://www.aqmd.gov/aqmp/docs/2003AQMPChap6.pdf.
[17] The entire text of this legislation can be read at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:h6enr.txt.pdf. This is found at the Government Printing Office's official web site.
[18] This is noted on the Energy Information Administration web site at http://www.eia.doe.gov/oiaf/aeo/index.html.

effects into EMPAX that would lead to reduced economic impact estimates such as how improvements in air quality lead to increased labor productivity.

Other caveats that can typically be applied to CGE analyses, including this one, cover issues such as transitional dynamics in the economy. CGE models such as EMPAX, which assume foresight on the part of businesses and households, will allow agents to adapt to anticipated policy impacts coming in the future. These adaptations may occur more quickly than if agents adopted a wait-and-see approach to new regulations. The alternative, recursive-dynamic structure used in CGE models such as MIT EPPA imply that no anticipation or adjustments will occur until the policy is in place, which tends to overstate the costs of policies.

Finally, in addition to transition dynamics, while CGE models are ideally suited for analyzing broad, economy-wide impacts of policies, they are not able to examine firm-specific impacts on profits/losses or estimate how particular types of disadvantaged households may be affected by policies. Similarly, environmental justice concerns may not be fully addressed.

5b.4 EMPAX-CGE Results for the Modeled Control Strategy

This section compares the modeled control strategy to a baseline for the economy that includes the current ozone standard (effectively, 0.084 ppm), along with other rules used to form the basis of the AEO 2007 forecasts by EIA such as the Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR). Impacts are measured assuming a 2020 implementation year and are the result of engineering costs described in Section 5.1. Thus, the following graphs compare the modeled control strategy to a baseline economic growth path in EMPAX-CGE that includes the current ozone standard and currently implemented legislation in the AEO 2007 forecasts.

5b.4.1 Projected Energy Impacts and Impacts on U.S. Industries of Incremental Costs From Modeled Control Strategy

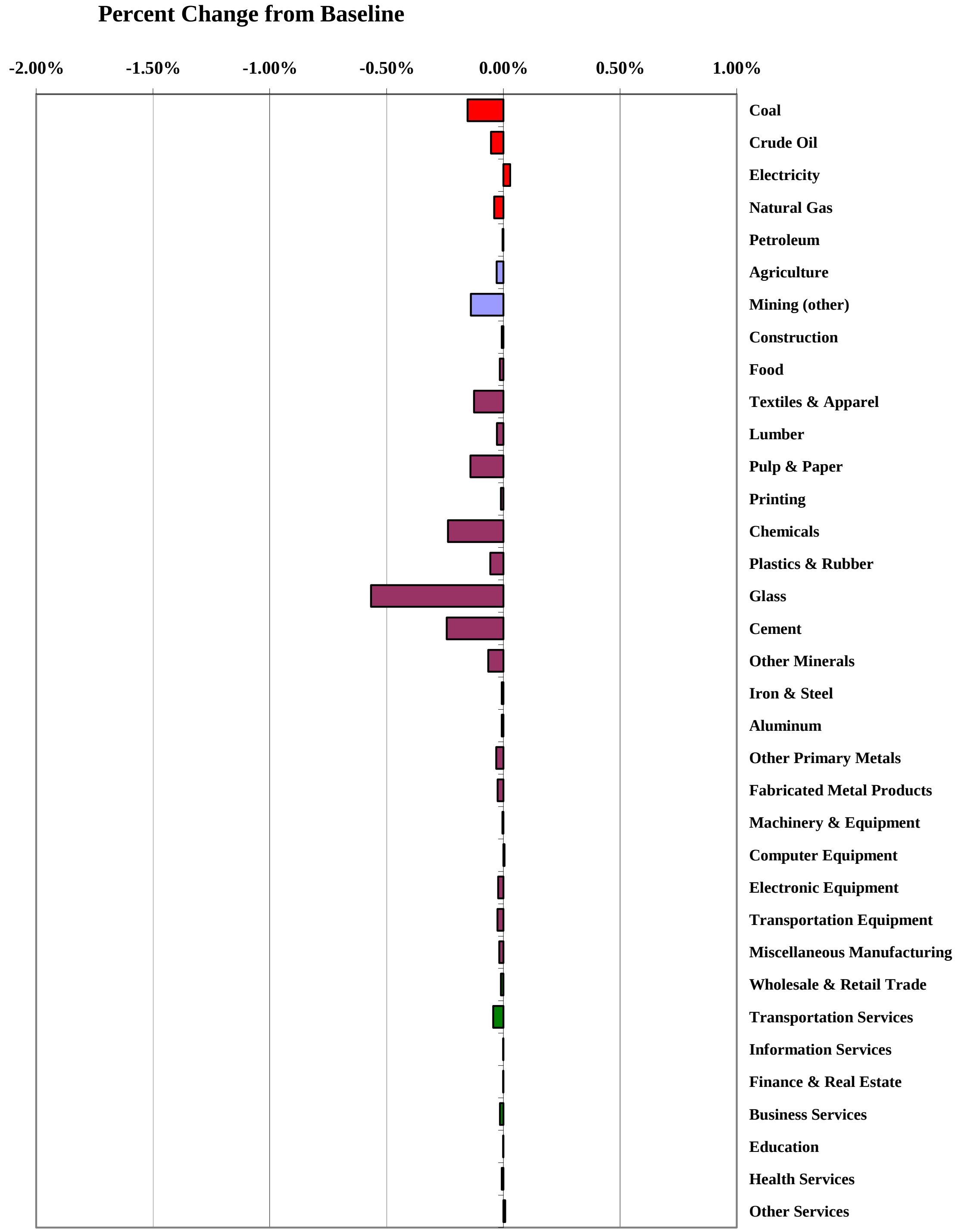
Impacts of the modeled control strategy on manufacturing costs can affect output and prices of all industries in the EMPAX-CGE model. These effects may increase or decrease output and/or revenue, depending on their implications for production costs and technologies and shifts in household demands. In general, the impacts on energy producers and other industries will be dependent on the control strategy and follow a pattern similar to the stringency of the ozone standard.

As shown in Figure 5b.3, impacts on energy and industrial output quantities are generally small across all industries for modeled control strategy. Outside of the energy-intensive sectors,[19] estimated changes in output of most manufactured goods are less than five one-hundredths of one percent (0.05%). Effects on coal output are somewhat higher, but impacts on other types of energy producers are low and can be positive or negative, which limits any spillover effects to other businesses and households. These changes in output quantities are different than any

[19] Energy-intensive sectors include food processing, pulp and paper, chemicals, glass, cement, iron and steel, and aluminum manufacturing. The definition of energy-intensive sectors applied in EMPAX-CGE is identical to that used by the U.S. Energy Information Administration (EIA) for their AEO modeling.

changes in gross output revenues, which include effects of changes in both quantity and output prices (which reflect changes in production costs) and may be either positive or negative, regardless of changes in output quantities. Also, across the economy as a whole, although there is almost no change in the quantity of services produced, these changes in output can potentially be larger in absolute terms than any changes in energy-related industries, which are much smaller than service industries in the U.S. economy. For more information on energy impacts at a nationwide level, please refer to Chapter 8 where we provide energy impact results in response to Executive Order 13211.

Figure 5b.3: Modeled Control Strategy Impacts on U.S. Domestic Output Quantity, 2020



Source: EMPAX-CGE.

As described in Chapter 3, selected control options for the modeled control strategy involve additional actions by electric utilities, which tend to slightly decrease coal consumption (influencing U.S. coal production) and increase natural gas use. EMPAX-CGE uses these findings on coal and gas use directly from the IPM model (as described in Appendix E in the RIA for the Final CAIR rule).[20] As part of its economy-wide estimation, EMPAX-CGE then considers how these changes in electricity markets affect other consumers of energy. Outside of electricity, other energy-producing industries also engage in additional measures, which can affect energy users such as energy-intensive manufacturers. Cement, chemicals and glass production are influenced by direct control costs on their respective industries and any changes in energy markets. Note, however, that across energy-intensive industries as a group, output quantities decline on average by less than a two-tenths of a percent (<0.2%).

5b.4.2 Projected Regional Impacts

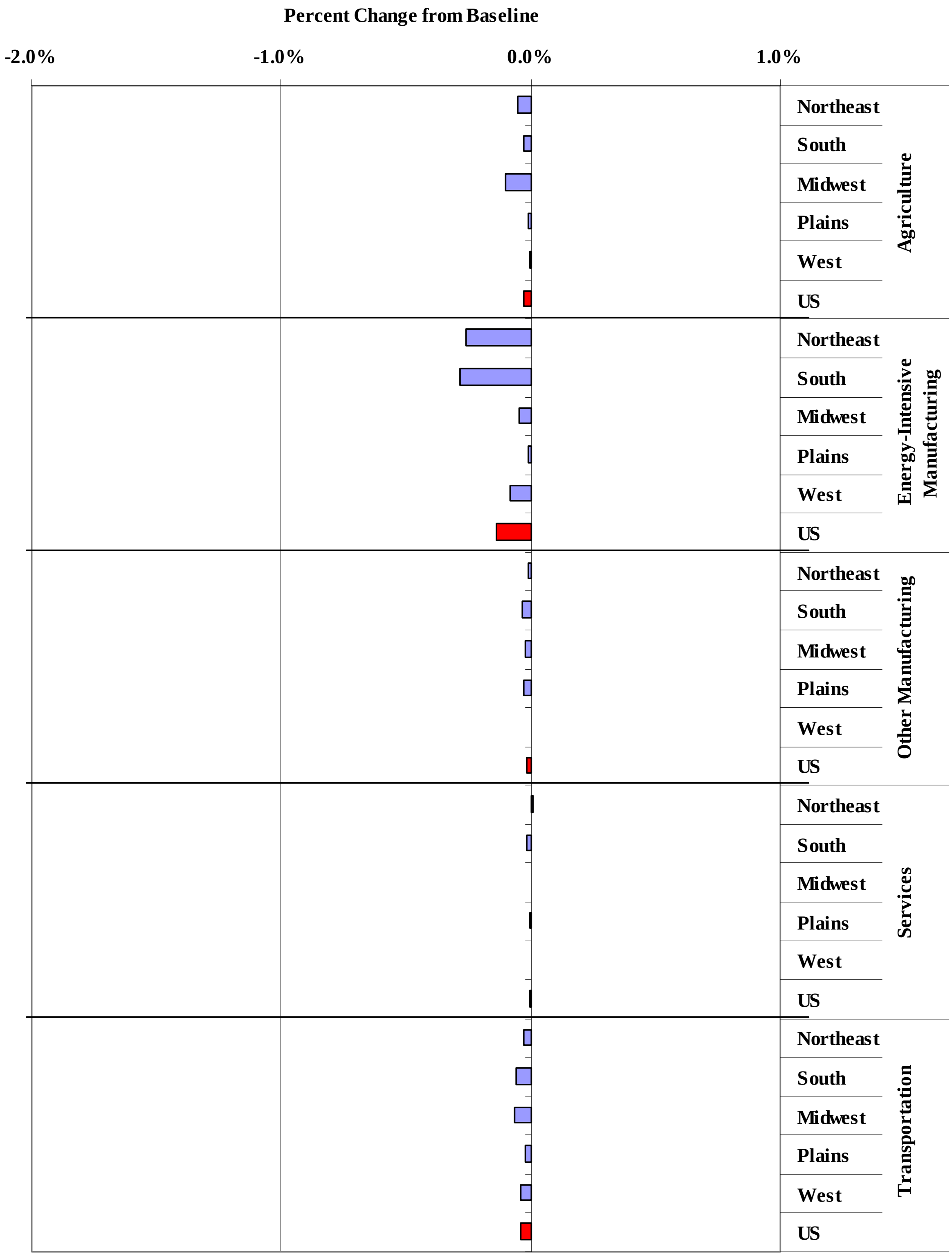
Regional effects will tend to show variation that does not appear at the national level. To examine how such variations might occur in response to the modeled control strategy, this section presents findings for selected industries and groups for the five regions in EMPAX-CGE. These divergences between average national impacts and regional effects arise from several sources such as:

- differences in control measures from the AirControlNET, IPM, and MOBILE models;
- differences in regional mixes of generation technologies (coal, gas, oil, and nonfossil use), which may be averaged out at a national level;
- differences in regional production and consumption patterns for electricity and nonelectricity energy goods;
- differences in industrial composition of regional economies;
- differences in household consumption patterns; and
- differences in regional growth forecasts.

Figure 5b.4 first presents regional impacts on industrial output from the modeled control strategy. Except for energy producers (shown in Figure 5b.5), this graph summarizes results for all the industries shown in Figure 5b.3, where similar industries are grouped together to facilitate the presentation. Aside from energy-intensive manufacturing (illustrated in more detail in Figure 5b.6), the adjustments in output are on the order of a few one-hundredths of one percent.

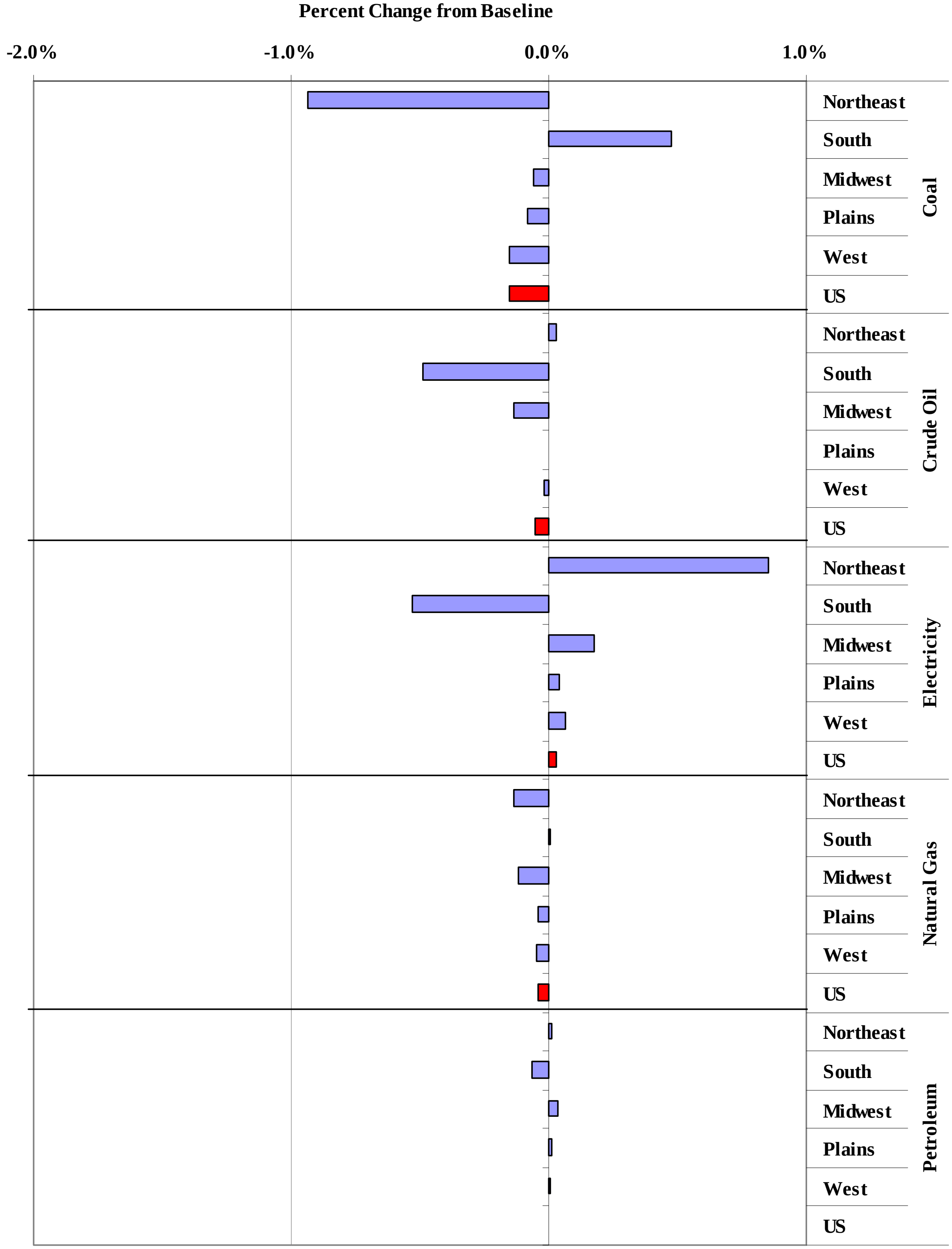
[20] See http://www.epa.gov/interstateairquality/technical.html for additional discussion of these linkages.

Figure 5b.4: Modeled Control Strategy Impacts on Regional Energy-Intensive Output Quantities, 2020



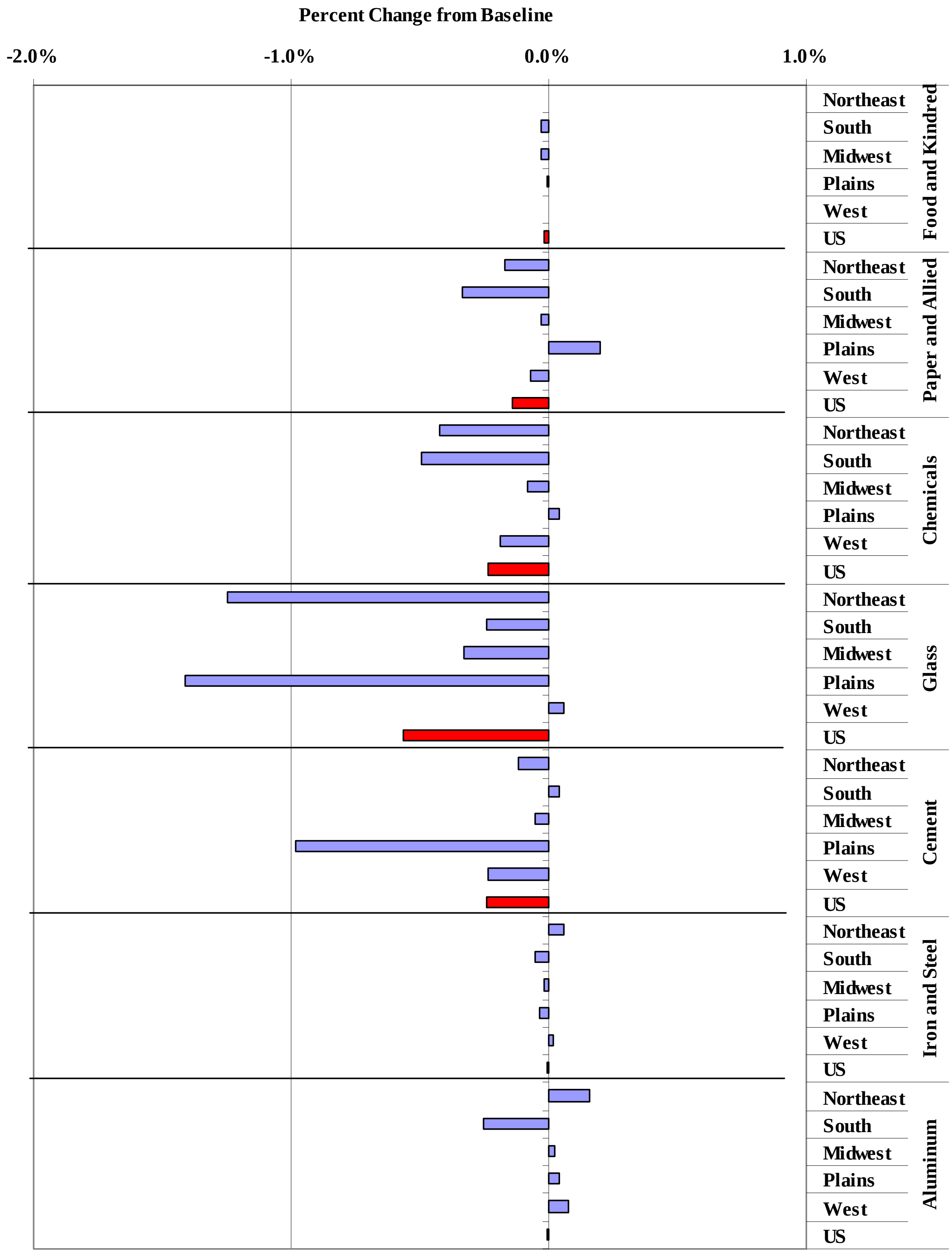
Source: EMPAX-CGE.

Figure 5b.5: Modeled Control Strategy Impacts on Regional Industry Output Quantities, 2020



Source: EMPAX-CGE.

Figure 5b.6: Modeled Control Strategy Impacts on Regional Energy Output Quantities, 2020



Unlike the broader industries, energy production that is more directly affected by the standards shows more regional variation than seen in the U.S. results in Figure 5b.3. However, all impacts are still less than one percent (<1.0%) across the regions with most adjustments smaller than that. Under the modeled control strategy, coal consumption by electric utilities tends to decrease slightly in 2020, except in the South. Natural gas use in electricity rises, but is offset by declines in other parts of the economy. Such results reflect the impacts from applying the EGU control strategy discussed in Chapter 3 of the RIA. This control strategy is applying primarily to EGUs in the Northeast and is applied only to coal-fired units. This leads to the costs of power generation becoming relatively cheaper in the South relative to the Northeast. Also, there are few controls applied to coal-fired EGUs in the South. The net impact from these effects is that EMPAX estimates that coal-fired power generation in the South decreases while it increases in the Northeast. These EMPAX results are shown in percentage and physical terms in Table 5b-2. The crude oil and petroleum refining industries react to the alternative standard by minor changes in output, although refining in some regions rises in cases where they may have a small comparative advantage as fewer refiners need to install additional controls.

Table 5b.2 Results from EMPAX in 2020 for Changes in Fuel Use and Generation by EGUs in Northeast and South Regions Under Modeled Control Strategy

Region	Baseline Use of Coal (trillion BTU) by EGUs	Use of Coal Under Modeled Control Strategy (trillion BTU)	Percent Difference in Coal Use (%)	Baseline Use of Natural Gas (trillion BTU) by EGUs	Use of Natural Gas Under Modeled Control Strategy (trillion BTU)	Percent Difference in Natural Gas Use (%)	Electricity Generation in Baseline (millions kWh)	Electricity Generation Under Modeled Control Strategy (millions kWh)	Percent Difference in Electricity Generation (%)
North-east	2,622	2,598	-0.9	871	870	-0.1	681,046	687,175	0.9
South	7,689	7,728	0.5	1,497	1,506	0.1	1,392,374	1,339,336	-0.5

BTU = British Thermal Unit

kWh = kilowatt-hour

Figure 5b.6 illustrates how changes in energy markets may affect those industries particularly reliant on energy inputs to their production processes. As with the U.S. average results from Figure 5b.3, even though the energy-intensive sectors show more regional variation, based on differences in production methods and changes in manufacturing costs, the majority of the impacts are on the order of a few tenths of one percent. However, there are measurable impacts in the output of specific industries. Under the modeled control strategy, energy-intensive output tends to be redistributed slightly from eastern to western regions as decreases in industries such as glass manufacturing in some regions are partially offset by increases in other regions.[21]

When examining such findings, however, it is important to note that these impacts and redistributions are directly related to the specific control strategy assumed in this illustrative analysis. As previously stated, these results represent the impact of the modeled control strategy presented by EPA. It is expected that States will evaluate the best strategies for achieving compliance and may choose options that could significantly alter these regional effects. Therefore, SIPs will likely be different than the strategy developed in this RIA and could be designed to alleviate any disproportionate impacts on sensitive industries. For example, given the impact on glass and cement production, assumed with this scenario, affected States may design SIP strategies that mitigate the impact on these particular industries, perhaps distributing costs more uniformly among all sectors.

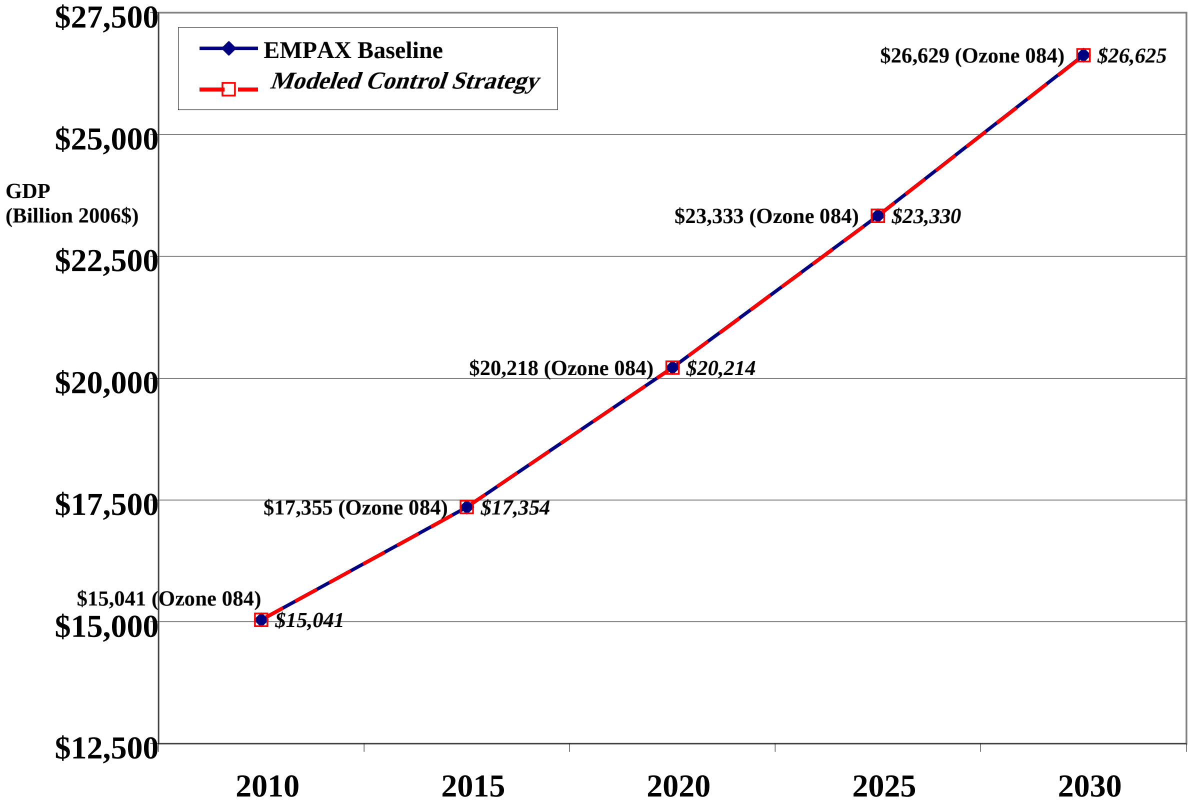
5b.4.3 Projected Macroeconomic Impact: GDP

The combination of economic interactions affecting business and household behavior will be reflected in the changes in GDP estimated by a CGE model. The impacts on GDP are provided here only for illustration of the macroeconomic impacts of this standard. They are not meant to illustrate the social costs associated with the modeled control strategy applied to attain the 0.070 alternate Ozone standard

Figure 5b.7 illustrates GDP in the EMPAX-CGE model's baseline forecast and the modeled control strategy. As shown, the estimated GDP impact is negligible and, in fact, it is not possible to adjust the scale of the graph to the point where the two lines do not overlap. Projected decrease in GDP for the modeled control strategy is roughly 0.02 percent (0.02%), respectively, for the year 2020. This is equivalent to a $3.6 billion decrease in GDP during the implementation year. In absolute terms, these estimated changes in U.S. GDP are extremely small relative to the total size of the economy. Even these small costs could be reduced if the CGE analyses were extended to include benefits associated with any alternate primary ozone standard such as improvements in labor productivity from environmental improvements.

[21] Redistribution of production will also tend to occur among states in each region, with some states' increasing output to offset any declines in neighboring states.

Figure 5b.7: Change in U.S. GDP Compared to EMPAX-CGE Baseline



Source: Department of Energy, Energy Information Administration; EMPAX-CGE

5b.4.4 Social Cost Approaches and Estimates

To provide an estimate of the social costs associated with the modeled control strategy, EMPAX-CGE monetizes welfare changes from the general equilibrium simulation using Hicksian equivalent variation (EV), which is related in concept to the producer/consumer surplus measures used in partial-equilibrium models. EV is a long-recognized technique to estimate welfare gains and losses in economic theory, having been developed by Sir John Hicks in 1939.[22] EV provides an estimate of the change in income that would provide an equivalent change in household welfare as the policy being considered and includes changes in utility households receive from both consumption and leisure time.[23] It is a technique that is widely used by economists to measure welfare change. For example, Chipman and Moore (1980) showed that

[22] Hicks introduced this concept into economic theory in his book "Value and Capital: An inquiry into some fundamental principles of economic theory," published in 1939.
[23] Including leisure time in the model and household decisions allows the labor supply to expand or contract in response to changes in wage rates, etc. It is also essential when modeling interactions between tax interactions and the economy.

EV is appropriate for welfare comparisons.[24] However, as calculated using EMPAX-CGE currently, it excludes measures of the standard's environmental benefits (e.g., environment, public health, and labor productivity). In addition, these social cost estimates from EMPAX-CGE do not incorporate extrapolated costs since these costs do not have a clear link to specific industries. The general equilibrium model estimates that the relative change in infinite-horizon[25] and average annual welfare losses are extremely small (approximately 0.025%). Over the 2005-2020 time horizon used in EMPAX-CGE for this analysis, the social costs are 93 percent of the engineering costs for the illustrative modeled control strategy when estimated in present value terms (2006 dollars).[26,27] We estimate social costs using a 5 percent real interest rate to discount future production and consumption as per EPA guidance from the SAB provided in 2003.

We use EV to provide an estimate of social costs in this analysis instead of a metric such as GDP since changes in GDP are a poor measure of impacts on consumer welfare. Although GDP is a common metric among policymakers for expressing "costs to society," it is a poor measure of "social costs." GDP as a measure of welfare has been criticized for many years by different economists. Much of that criticism is well summarized in a response to the 2004 Draft Thompson Report to Congress prepared by Arik Levinson and quoted as follows: "… GDP growth is a poor measure of welfare. It measures the flow of economic activity rather than the flow of assets. If there is over-fishing, regulations that reduce fish catch will reduce GDP in the short run, but increase long-run economic prosperity… Finally, GDP excludes non-traded benefits: environmental quality, health, workplace safety…" [28] Changes in household consumption are much closer to changes in the welfare of households (ignoring leisure) than changes in GDP. For example, since consumption is around two-thirds of GDP, a ballpark estimate might be that any changes in consumption will only be around two-thirds as large in dollar terms as changes in GDP. GDP also does not account for the value of leisure, which is accounted for directly in estimates of welfare impacts using an EV approach as mentioned above. Regarding exports and imports, GDP does account directly for the effect of export and

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[24] Chipman, John S., and James C. Moore. 1980. Compensating Variation, Consumer's Surplus, and Welfare. American Economic Review 70 (5): 933-49.

[25] By infinite horizon, what is meant is an infinite number of time horizons. Since it is not computationally feasible for EMPAX-CGE to provide estimates to this many time horizons, the model approximates an infinite horizon. Turn to p. 6-9 of the EMPAX-CGE documentation at http://www.epa.gov/ttnecas1/models/empax_model_documentation.pdf for details.

[26] It should be noted that we will not compare this social cost estimate with the benefits estimates for alternate primary standards presented later in this RIA. We do not make this comparison for two key reasons: 1) the lack of linkage between air quality changes and effect categories such as labor productivity and health care costs among households; and 2) our inability to provide extrapolated costs by industry to serve as input to EMPAX.

[27] As mentioned in Chapter 5, the engineering cost estimate for the modeled control strategy of $2.8 billion (2006$) is calculated using the Equivalent Uniform Annual Cost (EUAC) method. The EUAC method does *not* generate the present value of the annual costs of controls on a year-by-year basis from 2005 to 2020.

[28] Levinson, Arik. Response to 2004 Draft Report to Congress on the Costs and Benefits of Federal Regulation and Unfunded Mandates on State, Local, and Tribal Entities (or "Thompson Report"). Submitted to the U.S. Office of Management and Budget. June 2, 2004. Found on the Internet at http://www.whitehouse.gov/omb/inforeg/2004_cb/c.pdf.

imports upon U.S. expenditure on goods and services. The effect of purchasing imports upon household welfare as measured by the EV approach is accounted for indirectly through changes in household consumption and does not account for changes due to exports. We conclude thatThus, GDP is a poor metric for estimating welfare impacts in comparison to the EV approach, and therefore social costs. [29]

As part of being a dynamic, forward-looking model, EMPAX uses an interest rate to place a value on the future (including both the benefits of consumption and costs of production). We have been using a 5% real interest rate, based on the MIT EPPA model referred to earlier in this chapter and SAB guidance as discussed in U.S. EPA (2003). This interest rate will form the basis for how the model reacts to any engineering costs it sees coming in the future. Following the guidance provided in OMB's Circular A-4, we also provide social cost estimates in this appendix over the same 2005-2020 time horizon that reflect a 3% real interest rate, and a 7% real interest rate. These social cost estimates are 90 and 91 percent, respectively, of the engineering costs when costs are calculated in present value terms.

This is the first application of EV to estimate social costs as part of analysis using a CGE model in an RIA of this type. We intend to solicit review and advice from the SAB before its use in future economic impact analyses using CGE models.

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[29] We provide estimates of the changes in GDP in 2020 from implementation of the modeled control strategy in Chapter 6, but only to provide information on this commonly known macroeconomic metric.

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