Assessing the Economic Impact of Dominion Virginia Power's Coal-Fired Power Plant in Wise County, Virginia, Compared to Investments in Energy Efficiency

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Executive Summary

Dominion Virginia Power (DVP) recently began efforts to increase electric generating capacity in Virginia, citing rising electricity demand forecasts and a growing reliance on wholesale market purchases to meet this demand. The specific approach pursued by DVP, and approved in 2008 by the Virginia State Corporation Commission (SCC), is to construct and operate a 585 MW coal-fired power plant in Wise County, Virginia (hereinafter, the *Plant*). Although investing in new generating capacity is a traditional approach to meeting electricity supply needs, an alternative approach – based on reducing demand for electricity via investments in energy efficiency – may prove economically more beneficial to Virginia.

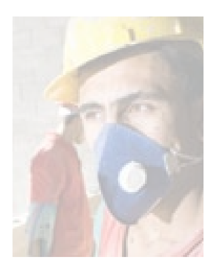
The Wise Energy for Virginia Coalition retained Abt Associates Inc. to assess the economic impact of the Plant and the alternative approach of relying on energy efficiency to offset the electricity needs that would otherwise be met by the Plant (the *Energy Efficiency Alternative*). This Executive Summary reviews the principal findings from these analyses and key elements of the analytic approach.

Specifically, we examined:

→ The economic impact of the Plant on the Company's Virginia customers and the broader Virginia economy. These impacts include Gross State Product (GSP) and employment effects in Virginia from (1) DVP's outlays for construction and operation of the Plant and (2) changes in electricity rates to business and residential customers due to the Plant.

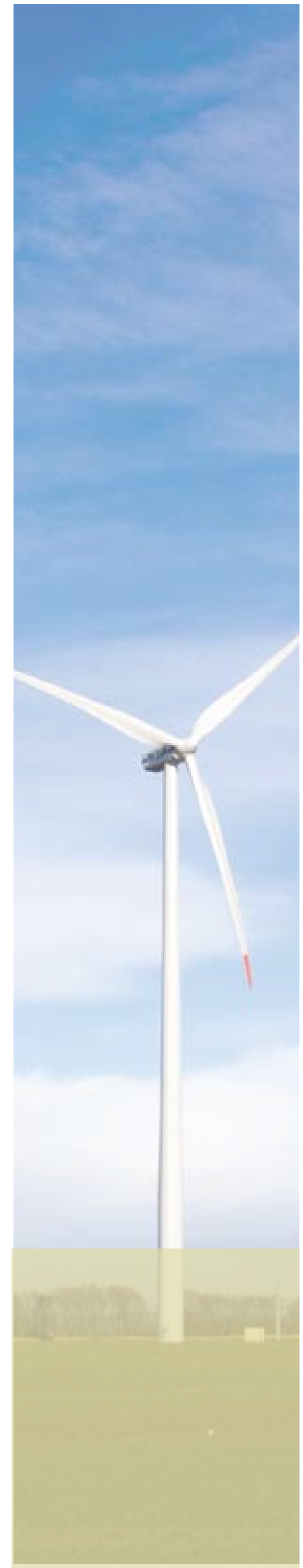
→ The economic impact on Virginia of meeting the electricity needs that would otherwise be served by the Plant via investments in energy efficiency. These impacts again include GSP and employment effects from (1) installing and maintaining the energy efficiency investments and (2) the changes in electricity rates to business and residential customers. Our analyses of the Energy Efficiency Alternative are based on low and medium cost cases, which were developed from an analysis of cost-effective energy efficiency opportunities in Virginia undertaken by the *American Council for an Energy-Efficient Economy*.

Overall, our analyses find that the Energy Efficiency Alternative would be less costly than the Plant for ratepayers, and substantially more beneficial to the Virginia economy in terms of Gross State Product (GSP) and job effects. The beneficial effects of energy efficiency are even more pronounced when a likely federal carbon emissions regulatory program is taken into account.



Of particular importance, our analyses account for the costs of federal carbon emissions regulation, *which constitutes significant cost not previously considered by DVP or SCC in their economic evaluations of the Plant*. Because coal has the highest carbon-content of electric power sources, carbon emissions regulation is likely to add considerably to the Plant's cost to Virginia ratepayers. We analyzed two carbon emissions regulation cases – *a low Permit Cost case*, using an initial permit price of $23 per ton of CO2-equivalent emissions, and a mid Permit Cost case, using an initial permit price of $39 per ton – for the analysis of the Plant and the Energy Efficiency Alternative. We also analyzed a *no carbon emissions regulation case*. However, given the strengthening consensus at the federal level to pursue a carbon emissions regulatory program, we view the carbon emissions regulation cases as providing the more realistic assessment of outcomes from Plant operation compared to the Energy Efficiency Alternative. The following summary emphasizes the findings from the carbon emissions regulation cases.

Below, we summarize key findings from our analysis of the Plant and the Energy Efficiency Alternative. We report results as annual values for three years we selected for our analysis: 2012, 2018, and 2025.



Impact on Electricity Rates

Our analyses indicate that the Plant will *increase* electricity rates for DVP's Virginia customers in all of the impact years, assuming the requirements of carbon emissions regulation. By contrast, under the Energy Efficiency Alternative, the total burden to Virginia ratepayers *declines*.

Two factors account for the difference in rate impact for the Plant and Energy Efficiency Alternative:

1. The Energy Efficiency Alternative achieves electricity demand reductions at a substantially lower cost (average of approximately $35-$60/MWh over the analysis years) than the cost of power generated by the Plant (average of approximately $100/MWh over the analysis years).

2. The Energy Efficiency Alternative will avoid the cost of carbon emissions regulation, whereas these costs are likely to be substantial for the Plant.

In both cases, the rate effects reported below are reduced by the avoided cost of purchased power, which is presumed to be displaced either by the Plant's electricity generation or by the reduction in demand through energy efficiency. The additional costs of carbon emissions regulation apply to the electricity production costs for the Plant *and* to the cost of purchased power. However, the burden of carbon emissions regulation on purchased power is lower than on the Plant's generation because purchased power is derived from a blend of energy inputs, which overall has lower carbon emissions intensity than the coal-based generation from the Plant.

As shown in *Figure ES-1* and *Figure ES-2*, below, the Energy Efficiency Alternative cases yield a substantial rate *reduction* for both residential and business customers. These reductions total in the tens of millions of dollars in each year, and exceed $100 million *annually* in future years under the carbon emissions regulation cases. In contrast, the Plant yields substantial rate *increases*, totaling in the tens of millions of dollars for all analysis years under the carbon emissions regulation cases. Under the no carbon emissions regulation case, the rate impact difference is less substantial; however, the Energy Efficiency Alternative remains substantially superior to the Plant in terms of overall rate impact.

For the average Virginia household, which consumes about 1,200 kWh of electricity per month, the rate effects for the *mid-permit* cost case are equivalent to an *additional cost* of $40 - $47 per year for the Plant, versus a *savings* of $30 - $50 per year for the mid-permit cost and *mid-efficiency* case under the Energy Efficiency Alternative (*see Figure ES-3*).[1]

1 *Figure 3* includes results for other analysis cases.

Combining these separate effects into a total *net* difference – i.e., the difference between the increased rates under the Plant *and* the rate reductions under the Energy Efficiency Alternative – yields a more comprehensive assessment of the monthly household cost effect. For example, under the *mid-permit cost* and *mid-efficiency cost* case, the average Virginia household would achieve net savings under the Energy Efficiency Alternative of $77 - $90 per year (compared to the estimated rate impact for the Plant).

Figure ES-1: Total Rate Effect for DVP's Virginia Residential Customers (millions)

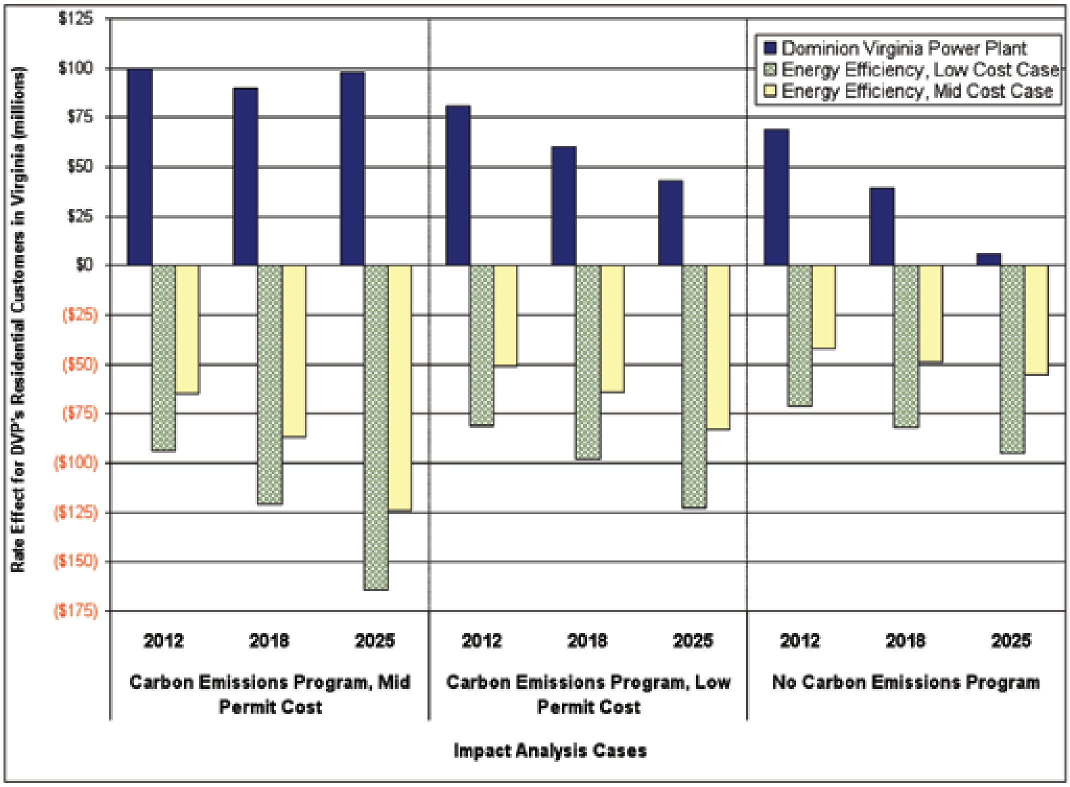


Figure ES-2: Total Rate Effect for DVP's Virginia Business Customers (millions)

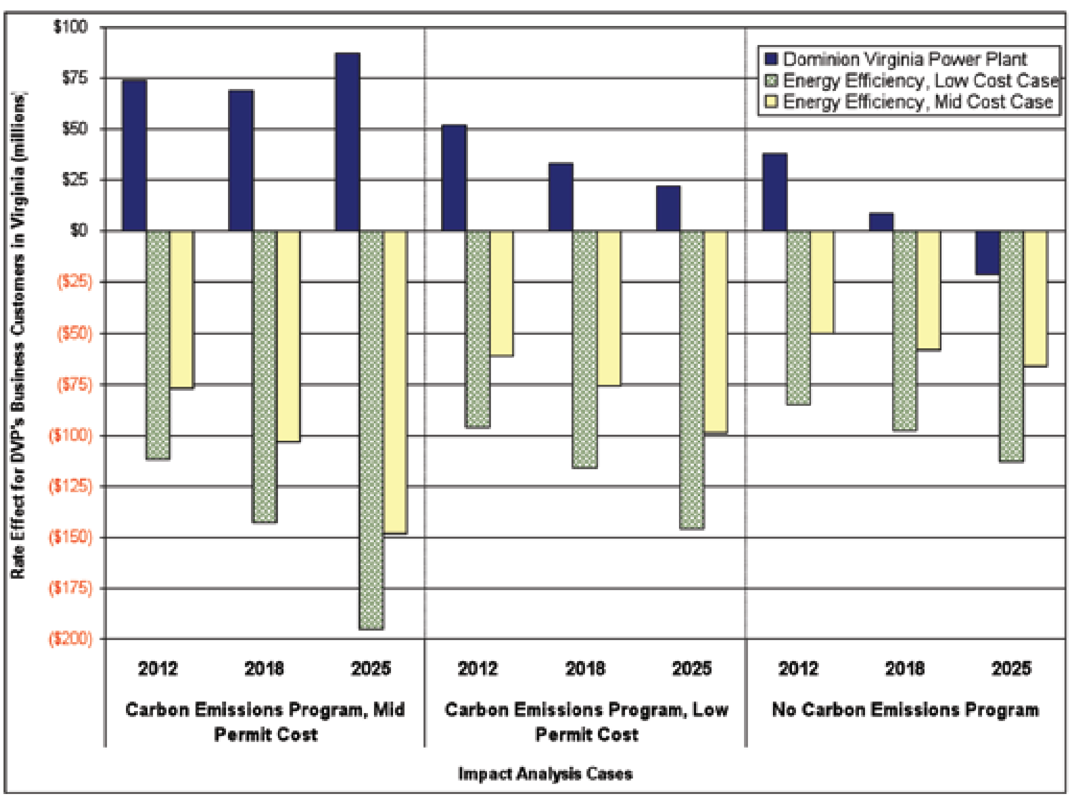
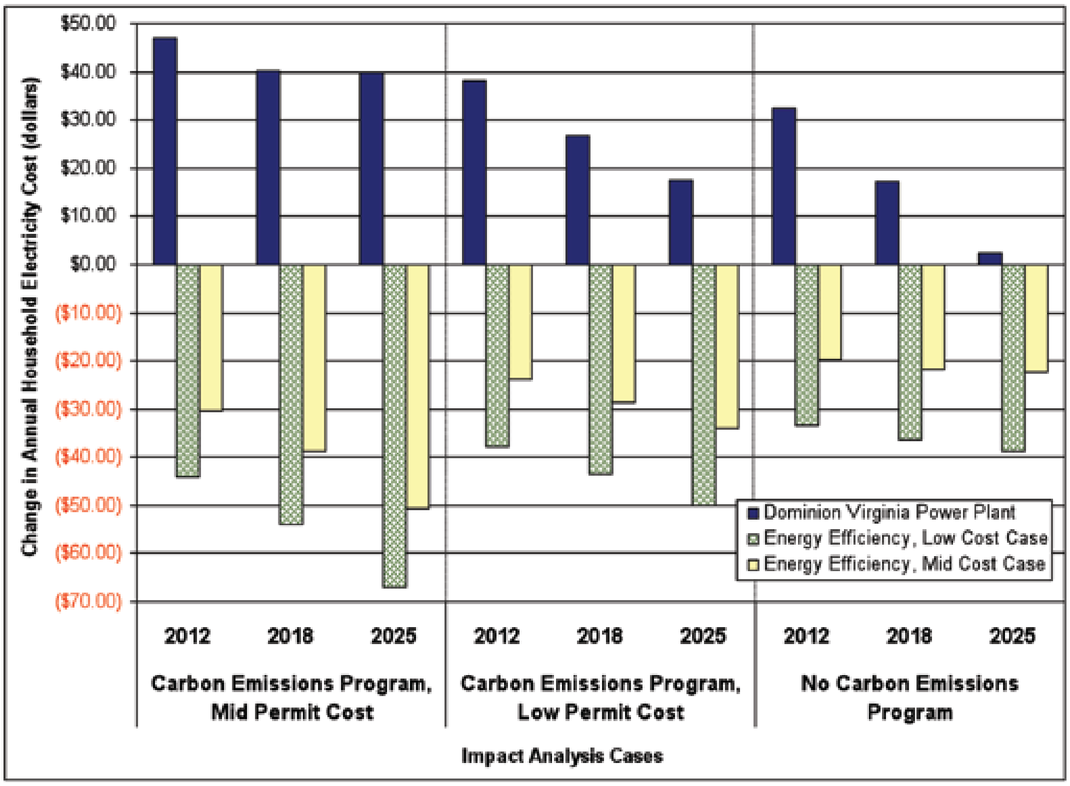


Figure ES-3: Impact of Energy Resource Options on Annual Household Electricity Cost



Gross State Product and Employment Impacts

Our analyses indicate that the Energy Efficiency Alternative will achieve substantially superior economic benefits for Virginia compared to the Plant.

The economic impacts of the Plant and the Energy Efficiency Alternative are summarized in *Figure ES-4* (change in Gross State Product – GSP), *Figure ES-5* (jobs), and *Figure ES-6* (employee earnings), below.

For the Plant, these figures capture the following economic effects in Virginia:

1. The economic effect of expendi *These effects are* *positive – i.e., increased GSP and jobs.*

2. The eco *These effects are generally negative, although less so in the no-carbon emissions regulation case.*

Similarly, for the Energy Efficiency Alternative, these figures capture the following economic effects:

1. The economic effect of the ex *These effects are* *uniformly positive.*

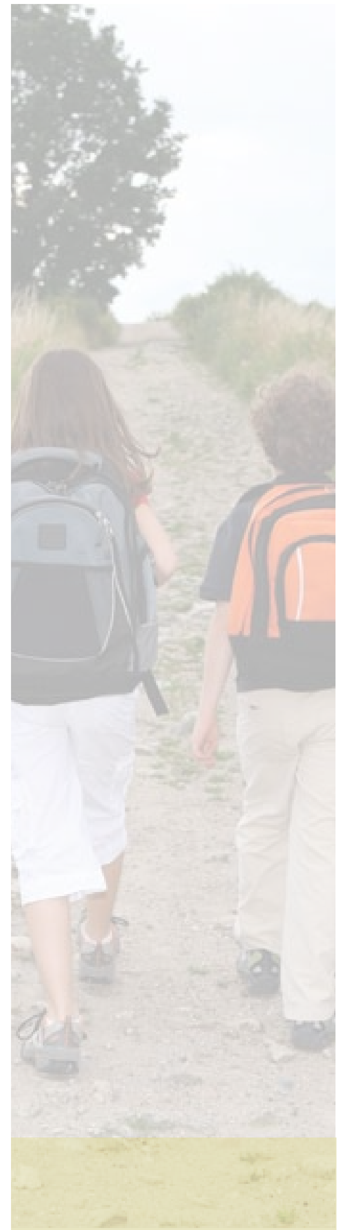
2. The eco energy efficiency policies and programs. *These effects are uniformly positive.*

For both the Plant and the Energy Efficiency Alternative, we calculated the total economic impact by summing the impacts from items (1) and (2), above.

As shown below, the Energy Efficiency Alternative achieves substantial benefits to the Virginia economy in all analysis cases – by carbon emissions regulation case, Energy Efficiency Alternative cost case, and analysis year. These benefits increase over time and also as the cost of carbon emissions regulation increases. In contrast, the Plant achieves substantially lower benefits, and these contributions diminish – *to essentially zero or negative* – as the cost of carbon emissions regulation increases.

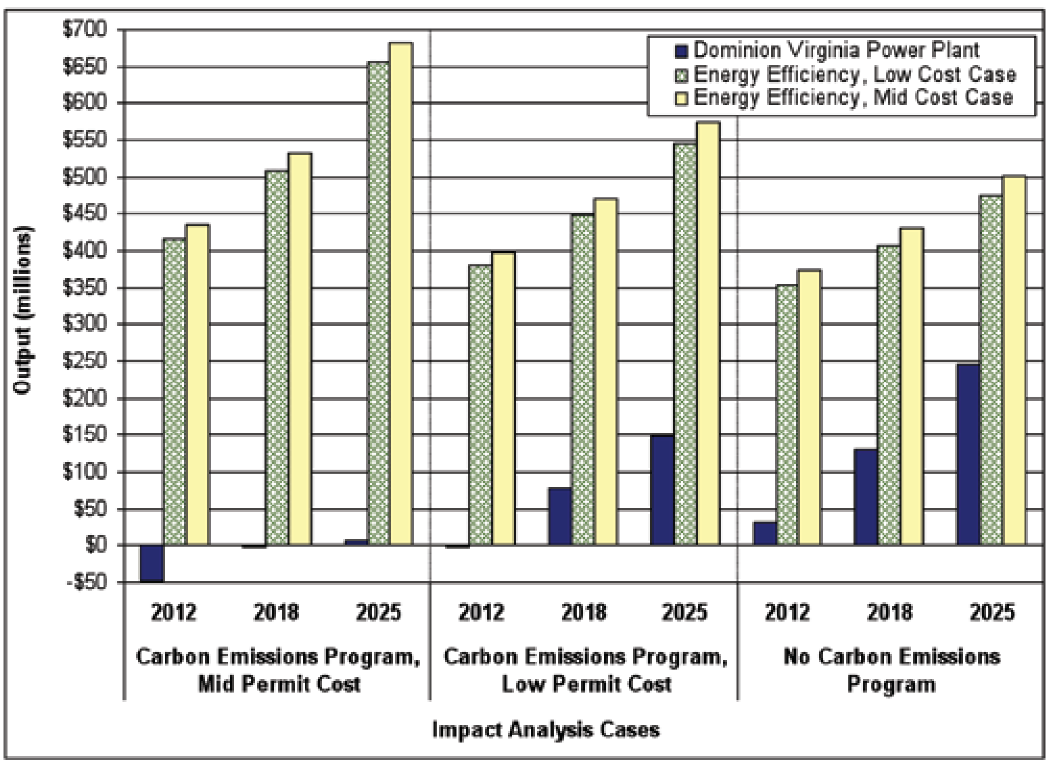
Under the *mid-permit cost* carbon emissions regulation case, the increase in Virginia GSP for the Energy Efficiency Alternative ranges from $415 to $435 million in 2012, and increases to a range of $655 to $680 million by 2025. The comparable values for the Plant are approximately *negative* $50 million in 2012 to a positive $10 million in 2012.

Under the *low-permit cost* carbon emissions regulation case, the increase in Virginia GSP for the Energy Efficiency Alternative ranges from $380 to $400 million in 2012, and increases to a range of $355 to $375 million by 2025. Comparable values for the Plant are essentially *zero* in 2012 to an increase of $150 million in 2025.



In the absence of carbon emissions regulation, the Plant uniformly contributes economic value to Virginia and this value increases with time; however, even here, the Plant's contribution is substantially less than the Energy Efficiency Alternative's contribution (see *Figure ES-4*, below).

Figure ES-4: Annual Impact on Gross State Product in Virginia ($ million)



The Plant also contributes to Virginia's economy during the construction period: our analyses indicate an annual average increase of $180 million in gross state product, 1,422 jobs, and $105 million in employee earnings over the four years of Plant construction. However, this benefit is short-lived and does not contribute to a sustained increase in economic activity in Virginia. In contrast, investment in energy efficiency can contribute to a sustained, long-term increase in GSP and jobs, and provides a skill and experience platform for extending the benefits of energy efficiency throughout the Virginia economy.

These GSP effects are accompanied by comparable impacts on jobs and employee income. Again, the Energy Efficiency Alternative achieves substantially more beneficial results than the Plant (see *Figure ES-5* and *Figure ES-6*, below).

Under the *mid-permit cost* case, the Energy Efficiency Alternative achieves employment gains of approximately 3,100 jobs in 2012, increasing to 5,000 jobs in 2025; employee income gains range from $130 million in 2012 to $210 million in 2025. Comparable values for the Plant are approximately 950 job losses in 2012, increasing to 1,000 job *losses* in 2025, and employee income losses of approximately $23 million in 2012, declining to $8 million in 2025.

Under the *low-permit cost* case, the Energy Efficiency Alternative achieves employment gains of approximately 2,850 jobs in 2012, increasing to 4,150 jobs in 2025; employee income gains range from $120 million in 2012 to $175 million in 2025. Comparable values for the Plant are approximately 570 job *losses* in 2012, reversing a *gain* of 130 jobs in 2025; employee income effects are $10 million in *losses* in 2012, reversing to a *gain* of $40 million in 2025.

As above, in the absence of carbon emissions regulation, the Plant contributes gains in jobs and employee earnings, in particular during the later years of Plant operation. However, the Plant's contributions are considerably smaller than those estimated for the Energy Efficiency Alternative.

Figure ES-5: Annual Impact on Employment in Virginia

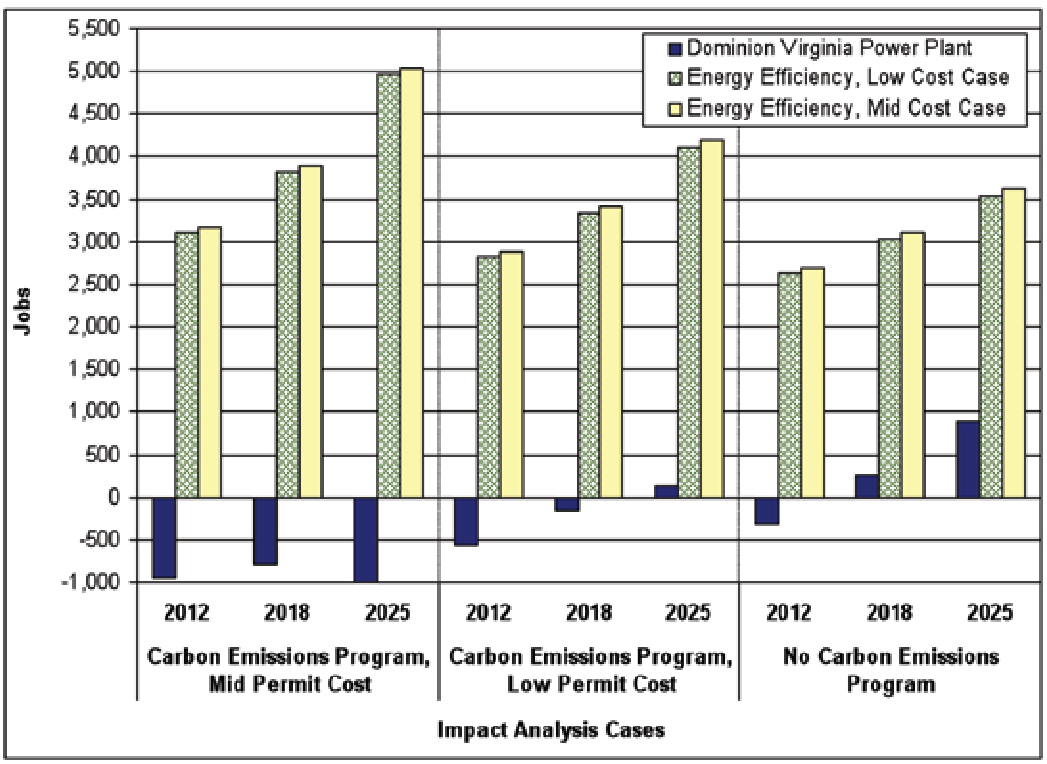
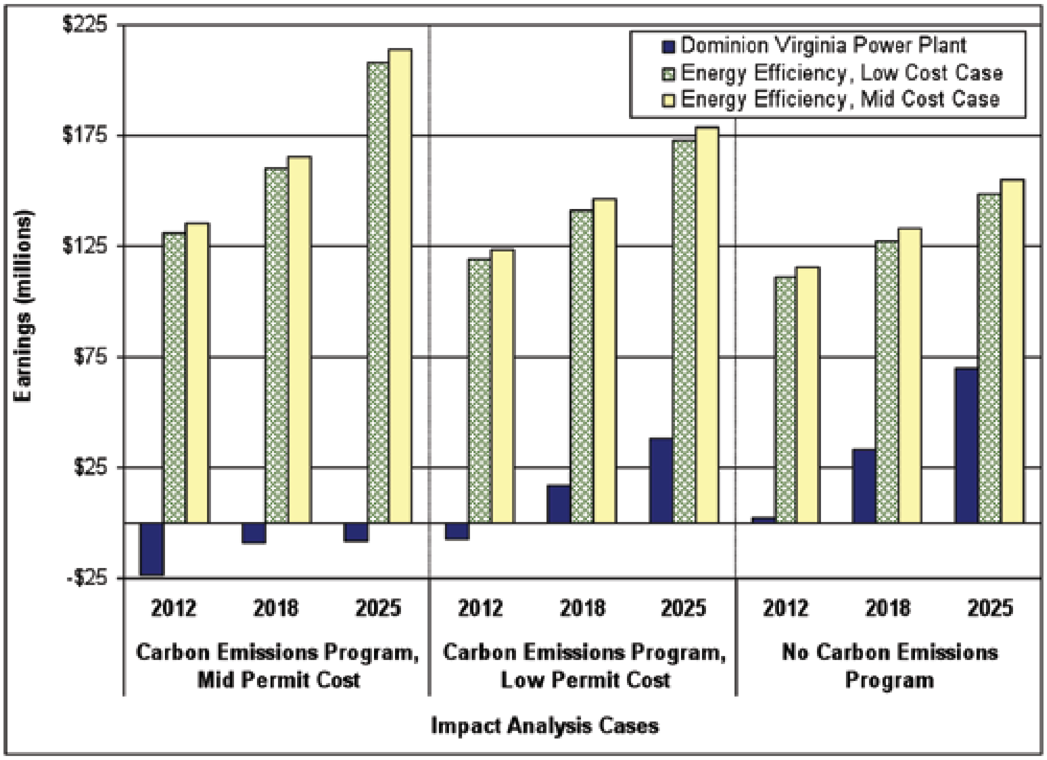


Figure ES-6: Annual Impact on Employee Earnings in Virginia ($ million)



Human Health Impacts from the Plant's Air Pollutant Emissions

In addition to assessing the effects on GSP and employment from the Plant and the Energy Efficiency Alternative as outlined above, we also analyzed the effect of the Plant's air pollution emissions on human health and related economic effects in Virginia. The Plant will be required to meet strict New Source Performance Standards (NSPS) for applicable pollutant emissions. However, because the Plant will burn a very large quantity of coal, it will still emit substantial air pollutants and these *allowed* emissions will adversely affect regional air quality and human health.[2] The Energy Efficiency Alternative has no such air pollution effects.

Our analysis of human health impacts focused on the effects of increased ambient concentrations of particulate matter less than 2.5 microns in aerodynamic diameter ($PM_{2.5}$), which is a harmful air pollutant linked with several serious health effects, including hospitalization for respiratory and cardiovascular illnesses, chronic bronchitis, and premature mortality. $PM_{2.5}$-related health effects result from the Plant's emissions of $PM_{2.5}$, as well as sulfur dioxide (SO_2), oxides of nitrogen (NO_x) and volatile organic compounds (VOCs), all of which contribute to the formation of $PM_{2.5}$.

In Virginia, pollutant emissions from the Plant are estimated to contribute to 2 - 5 additional premature mortality events on an annual basis[3]. In addition, these emissions will contribute to significant increased occurrence of non-fatal health impacts, such as bronchitis and other respiratory and cardiovascular ailments. The total *annual* economic value of these health impacts ranges from about $16 to $52 million for Virginia.

2 For example, the Plant is expected to emit about 1,900 tons of Nitrogen Oxides (NOx) and 600 tons of Sulfur Dioxide (SO_2) annually, along with a variety of other pollutants including particulate matter (PM) and volatile organic compounds (VOCs).

3 Adverse health effects are also estimated to occur in other near-by areas outside of Virginia.

Conclusion

From the standpoint of economic contribution to Virginia, we find that the Energy Efficiency Alternative offers a better approach than the Plant for meeting Virginia's electricity needs. The Energy Efficiency Alternative is substantially less costly for ratepayers, and substantially more beneficial to the economy in its effects on gross state product and employment. These superior benefits are even more pronounced when carbon emissions regulation is taken into account.

We emphasize that our analysis does not evaluate or presume to know which *specific energy efficiency policies/programs* or combinations thereof are the best options for Virginia, nor does this analysis intend to suggest that the Commonwealth consider *only* energy efficiency for meeting future energy needs. In addition, we recognize that material institutional barriers exist to pursuing the Energy Efficiency Alternative. For instance, under typical regulatory structures, utilities often do not have an economic incentive to offer energy efficiency or other demand-side programs because reduced electricity sales reduce utility revenues and earnings (Kushler et al. 2006).[4] However, a number of states and power companies have successfully pursued programs to include energy efficiency as a component of total energy resource planning and thereby reduce the need for new electric generating capacity.

In summary, this analysis demonstrates that energy efficiency can contribute a substantial economic gain compared with traditional supply-side approaches for meeting growing electricity demand and should be considered a priority energy resource as part of any integrated resource planning process.

4 Kushler, M., York, D., and Witte, P. 2006. *Aligning Utility Interests with Energy Efficiency Objectives: A Review of Recent Efforts at Decoupling and Performance Incentives.* American Council for an Energy Efficiency Economy (ACEEE) Report Number U061, October 2006.

Key Aspects of Our Analysis Approach

→ Our assessment of Plant costs and related effects builds from cost information in DVP's presentations before the SCC. The estimated electricity rate changes rely on conventional ratemaking principles in conjunction with electricity consumption, cost of capital, and other rate information in DVP's presentations. Our assessment of the *economic impact* of these rate changes is based, for residential customers, on the estimated effects on residential ratepayer spending in Virginia, and, for business customers, on the market response to efforts by these customers to pass on the rate changes in price increases, by affected economic sector, within the Virginia economy. Our analyses of the overall economic impact capture the effect of both rate changes and outlays associated with the Plant or the Energy Efficiency Alternative. These analyses rely on an input-output framework of the Virginia economy, which assesses the economy-wide effects of these changes in outlays and sector-specific economic activity levels.

→ Our analyses account for the cost of power that DVP *would otherwise continue to purchase* from the PJM Interconnection to meet electricity needs within its service territory. In both cases, these purchases, and their related rate impacts, are assumed to be avoided by either (1) operation of the Plant or (2) the reduction of electricity demand resulting from energy efficiency investments. *All analyses and reported results – for both the Plant and Energy Efficiency Alternative cases – are relative to a baseline in which DVP continues to purchase energy from PJM.*

→ The Energy Efficiency Alternative analyses are *based on an assumption that DVP would be entirely responsible for the cost of installing and maintaining these investments and administering the program to accomplish these investments, and that these costs would be passed on to electricity customers in electricity rates.* Two energy efficiency cost cases (*low* and *medium*) were developed based on an analysis of cost-effective energy efficiency opportunities in Virginia undertaken by the American Council for an Energy-Efficient Economy (ACEEE 2008).[5] The energy efficiency cost cases include the cost of energy efficiency-based reductions in electricity consumption *and* a substantial cost-adder to account for administrative and marketing costs.

→ Our analyses account for the cost of carbon emissions regulation. Although the final structure of eventual carbon emissions regulation cannot be known at this time, it appears very likely that an emissions permit program or carbon emissions tax will be implemented in the next few years. Under such a program, sources such as the Plant, which is expected to emit approximately 5.4 million tons of carbon dioxide per year, would incur additional costs to continue to emit carbon. Because coal has the highest carbon-content among electric generating sources, the relative cost burden to the Plant's generation is likely to be substantial. For our analyses, we relied on estimates of emission permit prices from several recent studies performed for the Lieberman-Warner Climate Security Act (S. 2191). We developed a *low cost case* (using an initial permit price of $23 per ton emissions) and a *mid cost case* (using an initial permit price of $39 per ton of emissions) for the analysis. We adopted a mid-range assumption that 50 percent of the Plant's carbon emissions – and emissions from purchased power providers – would incur the permit cost for the life of the analysis. Carbon emissions permit prices increase over time at rates indicated by the Lieberman-Warner Act analyses.

→ We escalated all costs – for energy inputs, purchased power, energy efficiency outlays, etc. – over time at appropriate rates of increase based on projected increases in energy costs and electricity prices and/or historical changes in the GDP Deflator.

→ The analysis of air pollution effects relies on the Co-benefits Risk Assessment (COBRA) Model, developed by Abt Associates for the U.S. Environmental Protection Agency.

5 See, American Council for an Energy-Efficient Economy (ACEEE). 2008. *Energizing Virginia: Efficiency First.* Report number E085, September 2008.

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1. Introduction

1.1 Background and Objectives

In July of 2007, Dominion Virginia Power, a subsidiary of Dominion Resources (hereinafter, the Company or DVP), submitted an application to the Virginia State Corporation Commission (SCC) for approval to construct and operate a coal-fired power plant in Wise County, Virginia. The Company, which is currently a net purchaser of both capacity and energy from the PJM market, indicated in testimony to the SCC that this generating plant is needed to meet growing demand for electricity and maintain reserve capacity requirements (source: DVP Morgan testimony).[6] The Company's application, including the proposed rate adjustment clause for cost recovery during the period of construction, was approved by the SCC in March of 2008.[7] Construction of the generating plant, called the Virginia Hybrid Energy Center (hereinafter, the Plant), began in June 2008.

The Plant has a nominal capacity of 585 MW and will consist of two circulating fluidized bed (CFB) boilers supplying steam to a single steam turbine generator. CFB boilers are designed to capture sulfur dioxide in the combustion process through the injection of limestone into the boiler. These boilers will also be equipped with post-combustion controls to reduce emissions of nitrogen oxides, particulate matter, and mercury. The CFB combustion technology utilized in the Plant has fuel flexibility, which allows other combustible materials – including coal, waste coal, wood waste, or municipal waste – to be burned.[8] According to the Company, the Plant is expected consume approximately 1.75 million tons of coal and up to 685 tons of biomass per year.

Appalachian Voices retained Abt Associates Inc. to analyze the economic impact of the construction and operation of the Plant on the Company's customers and the broader Virginia economy. As part of this analysis, we reviewed the SCC case proceedings as well as previous economic analyses of the Plant performed by the SCC[9] and Virginia Tech (Pease et al., 2007). Our review of these materials indicates that previous economic analyses failed to address several issues that have been raised with regard to whether this Plant represents the best overall approach to meeting the energy, economic, and environmental policy objectives of the Commonwealth of Virginia.

A key objective of this analysis is therefore to address and improve upon certain key concepts that were not examined during the SCC proceedings or in the Virginia Tech analysis, but are nevertheless critical for developing a robust understanding of the Plant's impact on the overall Virginia economy. These concepts include:

→ Assessment of the economic effect of plant construction and operation considering the Company's revised, higher estimate of the cost of the Plant.

→ Assessment of the economic effect of the changes in electric rates resulting from these higher estimated costs, with consideration of both the impact on residential customers and the impact on non-residential customers.

6 The Company currently relies on the PJM market for approximately 15% of its energy supply requirements.

7 All testimony provided during the SCC proceedings can be accessed via the SCC website (http://www.scc.virginia.gov/) using case number PUE-2007-00066.

8 For additional information on CFB technology, see the Department of Energy's website: http://www.fossil.energy.gov/programs/powersystems/combustion/fluidizedbed_overview.html

9 The SCC's economic analysis of the Plant is described in the pre-filed testimony of Mark K. Carsley, a Principal Research Analyst in the Commission's Division of Economics and Finance.

→ Assessment of the economic effect of an alternative approach to meeting Virginia's electricity needs via investment in energy efficiency (the Energy Efficiency Alternative), including the effects of both the outlays for energy efficiency and the impact on changes in electricity rates in Virginia.

→ Assessment of the cost of a potential carbon emissions regulatory program, which would apply both to the output of the Virginia City Plant and to DVP's purchases of electricity that would be displaced by (1) the Plant or (2) reduced electricity demand achieved via energy efficiency investments.

→ Assessment of the human health effects of the Plant's air pollutant emissions.

It is important to emphasize that this analysis relies substantially on data and assumptions that were presented by the Company during the SCC proceedings, and that Abt Associates could not independently verify in the course of this effort. Given the limited amount of publicly available, detailed information underlying certain of the Company's presentations regarding the Plant, we are limited in our potential to critique these inputs and judgments and/or to develop alternatives. To the extent that the Company's data or assumptions are reasonably disputable or uncertain, our analysis is therefore conservative in the sense that we have essentially given the Company the benefit of the doubt with respect to the cost and operating characteristics of the Plant.

1.2 Summary of Key Findings

We performed analyses for a number of cases capturing the analytical concepts outlined above. These cases include:

→ Analysis of the Virginia City Plant under three carbon emissions regulatory program cases:

- No Carbon Emissions Regulatory Program
- Carbon Emissions Program – *Low Permit Cost*
- Carbon Emissions Program – *Medium Permit Cost*

→ Analysis of the Energy Efficiency Alternative under two cost cases and each of the three carbon emissions regulatory program cases:

- Energy Efficiency Alternative – *Low Cost of Achieving Electricity Savings*
  - No Carbon Emissions Regulatory Program
  - Carbon Emissions Program – *Low Permit Cost*
  - Carbon Emissions Program – *Medium Permit Cost*
- Energy Efficiency Alternative – *Medium Cost of Achieving Electricity Savings*
  - No Carbon Emissions Regulatory Program
  - Carbon Emissions Program – *Low Permit Cost*
  - Carbon Emissions Program – *Medium Permit Cost*

Analysis results are reported as annual values in the years 2012, 2018, and 2025. *Table 1-1*, *Table 1-2*, and *Table 1-3* summarize the key findings of our analysis.

Table 1-1 reports the economic impact of the Plant, accounting for both (1) the outlays for Plant operation and (2) estimated changes in electricity rates over time. We found that the Virginia City Plant is likely to cause a relatively small gain to the Virginia economy (i.e., the negative economic impacts of the rate effects are outweighed by the positive impacts associated with Plant operations) in the absence of a carbon emissions regulatory program. With a carbon emissions regulatory program – which we judge as highly likely – the Plant initially causes a loss in the Virginia economy. Eventually, however, this loss is reversed, and the Plant again achieves a net gain to the Virginia economy by 2025.

Table 1-1: Aggregate Annual Economic Impact to Virginia, due to the Plant									
	Impact Analysis Year								
($ million)	2012	2018	2025	2012	2018	2025	2012	2018	2025
	No Carbon *Emissions Program*			Carbon Emissions Program – *Low Permit Cost*			Carbon Emissions Program – *Mid Permit Cost*		
Gross State Product	$32	$131	$247	-$1	$78	$149	-$48	-$1	$8
Employment (jobs)	-314	264	892	-569	-160	128	-947	-785	-1,001
Earnings	$2	$33	$70	-$8	$17	$38	-$23	-$9	-$8
Source: Abt Associates analysis									

In contrast, as summarized in *Table 1-2*, we estimate that the aggregate effect of the Energy Efficiency Alternative on the Virginia economy will be positive for all analysis cases and impact years. *Table 1-2* reports the economic impact of the Energy Efficiency Alternative cases, accounting for both (1) the economic effects of the energy efficiency outlays and (2) the associated changes in electricity rates. The beneficial effects of the Energy Efficiency Alternative increase both over time and with the increase in carbon emissions permit cost across analysis cases.

Table 1-2: Aggregate Annual Economic Impact to Virginia from the Energy Efficiency Alternative									
	Impact Analysis Year								
($ million)	2012	2018	2025	2012	2018	2025	2012	2018	2025
	No Carbon *Emissions Program*			Carbon Emissions Program – *Low Permit Cost*			Carbon Emissions Program – *Mid Permit Cost*		
Low Cost Energy Efficiency Case									
Gross State Product	$355	$407	$474	$379	$448	$546	$415	$508	$655
Employment (jobs)	2,625	3,028	3,530	2,818	3,348	4,108	3,104	3,821	4,962
Earnings	$111	$127	$149	$119	$141	$173	$131	$161	$208
Mid Cost Energy Efficiency Case									
Gross State Product	$374	$430	$502	$399	$471	$575	$435	$531	$682
Employment (jobs)	2,692	3,103	3,618	2,885	3,424	4,196	3,171	3,898	5,050
Earnings	$115	$133	$155	$123	$146	$179	$136	$166	$214
Source: Abt Associates analysis									

Overall, the Energy Efficiency Alternative appears to offer a significantly superior economic alternative to meeting Virginia's electricity needs. *Table 1-3* compares our findings from the two analyses summarized above. Each value represents the *gain in GSP, employment, and employee earnings* estimated to result from the Energy Efficiency Alternative compared to the Plant – i.e., Energy Efficiency Alternative results *less* Plant results.

Table 1-3: Aggregate Annual Economic Impact to Virginia from the Energy Efficiency Alternative									
	Impact Analysis Year								
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	No Carbon Emissions Program			**Carbon Emissions Program –** ***Low Permit Cost***			**Carbon Emissions Program –** ***Mid Permit Cost***		
Impact of the Low-Cost Energy Efficiency Case Compared to the Power Plant									
Gross State Product	$323	$276	$228	$380	$370	$397	$464	$510	$647
Employment (jobs)	2,940	2,764	2,639	3,387	3,507	3,980	4,051	4,607	5,963
Earnings	$109	$94	$79	$127	$124	$135	$154	$169	$216
Impact of the Mid-Cost Energy Efficiency Case Compared to the Power Plant									
Gross State Product	$342	$299	$255	$399	$393	$425	$483	$533	$675
Employment (jobs)	3,006	2,839	2,727	3,454	3,584	4,068	4,117	4,683	6,051
Earnings	$113	$100	$85	$131	$129	$141	$159	$174	$223
Source: Abt Associates analysis									

Table 1-3 shows that, when compared to an approach that procures an equivalent amount of electricity via energy efficiency, the Plant has a substantial *relative* negative impact on the Virginia economy.

Under the *mid permit cost* carbon emissions regulatory program case, the relative impact of the Energy Efficiency Alternative in terms of GSP ranges from $464 to $483 million in 2012, and increases considerably to a range of $647 to $675 million by 2025. These GSP impacts are accompanied by gains in terms of jobs and employee earnings in Virginia. Under the *mid permit cost* carbon emissions program case, the relative net employment gains average 4,874 to 4,950 jobs over the three analysis years, depending on the efficiency case. Relative net gains in employee income average $180 to $185 million over the three years.

As we discuss in *Chapter 4: Assessing the Energy Efficiency Alternative*, we recognize that institutional barriers exist to pursuing the Energy Efficiency Alternative. For instance, under typical regulatory structures, utilities often do not have an economic incentive to offer energy efficiency or other demand-side programs because reduced electricity sales reduce utility revenues and earnings (Kushler et al. 2006). In addition, we recognize that the Energy Efficiency Alternative, as outlined in this report, represents an illustrative case based on cost-effective energy efficiency *potential*, rather than a specific set of energy efficiency measures or a program to implement those measures. Nevertheless, this analysis – and real-world examples – demonstrate that energy efficiency can contribute a relative economic gain compared with traditional supply-side approaches for meeting growing electricity demand and ought to be considered a priority energy resource as part of any IRP process.

In addition to assessing the effects on GSP and employment from the Plant and the Energy Efficiency Alternative as outlined above, we also analyzed the effect of the Plant's air pollution emissions on human health and related economic effects. The Energy Efficiency Alternative has no such air pollution effects. In Virginia, we find that the increased pollutant emissions are estimated to contribute to 2 - 5 additional premature mortality events on an annual basis.[10] In addition, these emissions will contribute to a significant increased occurrence of non-fatal health impacts, such as bronchitis and other respiratory and cardiovascular ailments. The total annual economic value of these health impacts ranges from about $16 to $52 million for Virginia.

10 Adverse health effects are also estimated to occur in other near-by areas outside of Virginia.

1.3 Organization of this Report

The remainder of this report is organized as follows:

→ **Chapter 2** assesses the economic impact of Plant construction and operation

→ **Chapter 3** assesses the economic impact of changes in electricity rates due to the Plant

→ **Chapter 4** assesses the economic impact of the Energy Efficiency Alternative

→ **Chapter 5** compares the economic impact findings for the Plant and the Energy Efficiency Alternative

→ **Chapter 6** assesses the human health impact of the Plant's air pollutant emissions

2. Assessing the Economic Impact of Plant Construction and Operation

Chapter Summary

Dominion Virginia Power is constructing of a 585 MW, $1.8 billion dollar coal-fired power plant in Wise County, Virginia. This chapter analyzes the economic impact on the Company's customers and the broader Virginia economy of the outlays for constructing the Plant and the annual outlays for Plant operation.

Abt Associates performed this analysis using a framework developed by the Department of Energy's National Renewable Energy Laboratory for analysis of coal-fired generating facilities. The key uncertainties in this analysis arise from our reliance on unverifiable cost and operating characteristics for the Plant provided by the Company, and in some cases, conservatively specified default values provided in the modeling framework.

Constructing the Plant will produce a temporary increase in economic activity equivalent to about 5,700 job-years, $419 million in total labor income, and $720 million in gross state product (GSP) cumulatively during the four-year construction phase. Thereafter, Plant operations may sustain up to 854 new jobs in Virginia, $45 million in labor income, and $160 million in GSP on a more permanent basis. Given the character of uncertainty in the analysis inputs, we judge these results to be relatively high estimates within the range of plausible results.

We emphasize that this analysis does not account for the economic effects of the increase in electricity rates to DVP's Virginia customers to recover the costs of the Plant's construction and operation. The analysis of these offsetting effects is described in *Chapter 3*. Moreover, *Chapter 4* assesses the alternative approach using energy efficiency to meet electricity demand, and finds that this approach offers superior economic benefits at a lower cost to ratepayers.

2.1 Analysis Approach for Modeling Plant Construction and Operations

We assessed the economic impacts arising from the construction and operation of the Plant using the Job and Economic Development Impact (JEDI) modeling framework developed by the Department of Energy's National Renewable Energy Laboratory for analysis of coal-fired generating facilities.[11]

The JEDI-Coal model is a state-level, input-output modeling framework that uses a set of key Plant-specific characteristics to estimate the portion of total project expenditures (e.g., labor, services, materials) that are spent in a state, and subsequently, the number of jobs, earnings, and economic activity that accrue to the state as a result of supply linkages in the local economy. For example, expenditures on power generation-related goods and services affects local economic activity as a result of both their initial direct expenditure and the increased demand for goods and services in linked sectors that are driven by these expenditures.

These economic effects are classified into categories of direct, indirect, and induced effects:

→ ***Direct effects*** include changes in jobs, income, and economic activity associated with the on-site or immediate effects created by a given expenditure – for example, the on-site jobs hired and materials purchased to construct the Plant.

→ ***Indirect effects*** refer to changes in jobs, income, and economic activity in upstream-linked sectors in the Virginia economy that supply materials and services to the directly affected sectors.

11 The JEDI modeling framework can accessed at: http://www.nrel.gov/analysis/jedi/about_jedi.html

→ ***Induced effects*** refer to changes in jobs, income, and economic activity that are induced by the spending of those persons directly and indirectly affected by the project. These effects occur when the income generated by the direct and indirect effects is re-spent in the local economy.

Aggregate economic effects in Virginia (whether for the construction or operation phase of the Plant) are estimated by summing the direct, indirect, and induced effects. To accomplish this analysis at the state-level – in this case for Virginia – JEDI uses a set state-specific input-output multipliers and personal consumption expenditure patterns based on data from the IMPLAN Group for the year 2006.[12]

2.2 Data for Modeling Plant Construction and Operations

The analysis of Plant construction and operations uses data provided by the Company during the SCC proceedings and conservatively specified default values provided in the JEDI framework.

The developers of JEDI conducted extensive interviews with power generation project developers, state tax representatives, and others in the electric power industry to determine appropriate default values for the model. Default values provided in the model represent average cost and spending patterns for coal plant construction projects in Virginia. However, recognizing that assumptions made regarding the magnitude and structure of Plant-related expenditures play an important role in influencing the results, we relied as much as possible on Plant-specific information contained in the Company's testimony during the SCC proceedings.

Key inputs to the JEDI modeling framework gathered from the Company's testimony to the SCC are described below and summarized in *Table 2-1*:

→ ***Construction cost.*** The Company initially stated in its July 13, 2007 filing with the SCC that the 585 MW Plant would be constructed over a 48-month period, coming online in 2012, at a total cost of $1.62 billion. The total cost of the Plant was subsequently revised upward to $1.8 billion, or $3,077/KW (source: DVP Bolton rebuttal testimony).

→ ***Capacity factor.*** The Company asserts, based on the Plant's cost structure and the performance of CFB technology at other generating facilities, that the Plant will achieve a 90 percent capacity factor (source: DVP Martin rebuttal testimony).

→ ***Heat rate.*** The Company estimates that the Plant will achieve a heat rate of approximately 10,000 BTU/kWh (source: DVP Martin testimony).

→ ***Cost of fuel.*** Fuel and variable operating and maintenance (O&M) expenses are estimated to range from $1.70 to $1.80 per MMBtu in 2012, the first year of Plant operation (source: DVP Martin testimony).

→ ***Fuel produced locally.*** In testimony to the SCC, the Company stated that it intends to use a local fuel source to operate the Plant, and in fact the characteristics of Southwest Virginia coal were a key basis for selecting a CFB technology.[13] In addition, the Company commissioned a study by Miltech Energy Services to evaluate the availability of local fuel sources to operate the Plant. According to the Company, this study showed that the relatively low heat content of coal available near the Plant is in less demand than other coals that are exported from the Virginia coalfield region, and that a supply sufficient to meet Plant needs exists within a 50-mile radius of the Plant (source: DVP Martin rebuttal testimony).

12 See Minnesota IMPLAN Group (MIG) (http://www.implan.com/). MIG compiles and aggregates economic data to calculate the relationship between changes in demand for goods and services, and resulting total economic activity, at the local, state, and regional level. NREL's framework uses IMPLAN data to calculate economic activity resulting from changes in demand for goods and services due to coal and other energy project construction and operation.

13 The Plant was designed based on a fuel specification having an average heat content of approximately 7,700 BTU/lb, which is consistent with the fuels located in Southwest Virginia.

Table 2-1: Key Project Inputs Specified in the JEDI Framework	
Project Data Element	**Plant Specification**
Project Location	Virginia
Year Construction Starts	2008
Project Size - Nameplate Capacity (MW)	585
Capacity Factor (Percentage)	90%
Heat Rate (Btu per kWh)	10,000
Construction Period (Months)	48
Plant Construction Cost ($ billion)	$1.8
Plant Construction Cost ($/kW)	$3,077
Cost of Fuel ($/mmbtu)	$1.75
Fuel Produced Locally (Percent)	100%
Source: Abt Associates analysis	

Other key inputs specified in the JEDI modeling framework include fixed O&M expenses, the portion of project expenditures that are purchased locally (e.g., in Virginia), and local property tax information:

→ ***Fixed O&M.*** The Plant's fixed annual O&M costs (specified on a $/kW basis) include labor costs for plant operators, maintenance workers, administrative staff and management, contract services and support labor, and related material costs. Information to specify the fixed O&M costs of the Plant is not available in the Company's testimony during the SCC proceeding. Therefore, we used the JEDI default assumption of $40.00/kW.

This default value for the fixed O&M cost assumes that approximately 20% is for labor, 47% is for materials, and 33% is for services. The cost of labor assumes an average annual salary for each employee of approximately $58,000 per year, plus a 38% mark-up for additional employee expenses (e.g., health benefits, disability insurance, workers compensation, etc.), for a total average annual employee cost of approximately $80,000 per year. We judge these values to be reasonable given prevailing wages reported by the Bureau of Labor Statistics for Southwestern Virginia,[14] but to the extent that actual wages and/or benefits paid to Plant employees differ from these assumed values, total Fixed O&M costs for the Plant may be over- or understated.

→ ***Local share of expenditures.*** The use of local labor and materials *significantly* affects the ultimate magnitude of economic effects that accrue in Virginia. Although most coal-fired power plants follow a similar expenditure pattern with respect to total construction and O&M costs, the *share* of local spending can vary substantially depending on a project's location and the availability of local labor and materials. Due to a general lack of information in the case proceedings regarding the share of expenditures expected to occur in Virginia during the construction and operation of the Plant, we relied on the default local expenditure patterns provided in JEDI. *These parameters are critical to the results, and therefore, represent a significant uncertainty in our analysis and may overstate the fraction of materials and other services purchased in Virginia to the extent that the Company purchases Plant equipment outside Virginia.*

- *Construction phase.* During the Plant's construction, the JEDI modeling framework assumes that approximately 50% of the labor will come from local contractors and approximately 75% of construction materials and other services will be purchased in Virginia.
- *Operations phase.* During the Plant's operation, the JEDI framework assumes that the following operation expenses will occur in Virginia: 100% of the Plant employee expenditures, 100% of water purchases and ash/sludge disposal, 85% of fixed O&M services, and 25% of fixed O&M materials.

14 See http://www.bls.gov/oes/current/oes_5100001.htm, accessed 12/19/2008.

→ ***Local property taxes.*** JEDI requires three parameters for estimating local property tax effects: the *assessed value* (percent of construction cost), the *taxable value* (percent of assessed value), and the *local property tax rate* (percent of taxable value). The JEDI framework accounts for the effects of the subsequent expenditure of the additional property taxes by government; however, we did not specify a slate of public services or projects that would benefit from the Plant's property taxes.

We did not use the default values in the JEDI framework to specify the property tax parameters. Instead, we used parameter values specific to Virginia that were developed by Tegen, Goldberg, and Milligan (2006) as part of a demonstration project of the JEDI framework performed by the JEDI developers:

- Assessed value (percent of construction cost) = 85%
- Taxable value (percent of assessed value) = 73%
- Local property tax rate (percent of taxable value) = 0.1%

For that analysis, Tegen et al. used average rates from examples provided by the State Corporation Commission. As shown above, although the taxable value is high, the local tax rate is only about one-tenth of average rates. As a result, the property tax payment ends up on the low end of the range of average property taxes.

To the extent that these default assumptions vary from the actual local expenditure patterns during the Plant's construction and operation, the estimates of economic impacts may be over- or understated. Sensitivity analyses performed by the developers of the JEDI framework indicate that the largest contributors to economic impacts in a state's economy from a new coal-fired electricity generation facility are directly related to fuel purchases, property taxes, percent of local labor used, and the cost of O&M (Tegen, Goldberg, and Milligan, 2006). Nevertheless, we believe that this analysis is based on sufficient project-specific information to provide a reasonable expectation about the magnitude of potential impacts from the Plant. The results of the JEDI analysis for the construction and operation of the Plant are presented below in *Sections 2.3* and *2.4*.

2.3 Estimating the Economic Impact during the Construction Phase

Table 2-2 summarizes the cumulative economic impacts of Plant construction on the Virginia economy in terms of employment, labor income, and output over the 4-year construction period.

The total cost of the Plant – assuming no additional cost escalation – is $1.8 billion dollars, approximately $450 million of which is estimated to be spent in each year of the 4-year construction period.

Table 2-2: Summary of Economic Impacts in Virginia, during Construction Period (2008 – 2012) (millions of 2008 dollars)

Impact Tier	Jobs[a]	Earnings	Gross State Product
Direct Impacts	3,354	$324	$449
Indirect Impacts	968	$43	$113
Induced Impacts	1,368	$52	$158
Total Impacts	5,689	$419	$720
Total Impacts, average annual	1,422	$105	$180

[a] *Job impacts are full-time job-year equivalents for the 48 month construction period.*
Source: Abt Associates analysis

The results indicate Plant construction may sustain up to 5,700 full-time job-years in Virginia (the vast majority of which occur in Virginia's construction sector, as expected), $419 million in total labor income, and approximately $720 million in GSP. These values are cumulative over the four-year construction period. The annual values for *each of the four years* would be approximately one-fourth of these totals.

The following considerations should be taken into account in interpreting these economic impacts:

→ First, these economic impacts cannot be added together; rather, these are measurements of three different manifestations of the economic effects arising from Plant construction.

→ Second, given the requisite use of conservatively specified default values and simplifying assumptions described in the previous section, *particularly with respect to the share of expenditures that occur locally*, the results of this analysis should not be interpreted as precise values. Given the character of uncertainty in the input values, we judge these results to be relatively high estimates within the range of plausible results.

→ Third, it is important to emphasize that the economic effects arising from construction are temporary, one-time effects, which will be realized during the Plant's construction, and are not a permanent addition of economic activity to the Commonwealth of Virginia.

→ Fourth, this analysis does not consider the potential for additional escalation of the Plant's total cost.[15] As indicated in the Company's testimony to the SCC, the Plant requires significant levels of long lead equipment, and optimum execution during the construction phase is dependent on timely performance at each level of the requisite supply chain. The potential risk for cost escalation notwithstanding, we believe this consideration represents a *relatively* small uncertainty in the analysis given the Company's statement that they have secured a fixed-priced contract for construction that covers 86% of the estimated total cost (source: DVP Martin testimony);

→ Fifth, as noted previously, the analysis of construction-related economic impacts presented in this section does not account for the economic impact of the electricity rate increase for the Company's ratepayers to recover the cost of the Plant. Nor does this component of our analysis account for the net economic impacts of the Plant compared with alternative approaches for meeting demand for electricity in Virginia. These analysis concepts are described in *Chapters 3* and *4*, respectively.

→ Lastly, although the Company claims in the SCC case proceedings that the Plant is designed to be "carbon capture compatible," the Company has not estimated the potential additional capital outlay required to install Carbon Capture and Sequestration (CCS) technology at the Plant or the timing of that outlay. In fact, the Company acknowledges that no commercially viable CCS technology is available. This analysis therefore does not consider the additional cost, and associated economic effects, from installing CCS technology at the Plant.

2.4 Estimating the Economic Impact during the Operations Phase

Table 2-3 summarizes the annual economic impacts arising from Plant operations on the Virginia economy in terms of employment, labor income, and output.

Table 2-3: Summary of Annual Economic Impacts in Virginia, during Operations Period (millions of 2008 dollars)

Impact Tier	Jobs[a]	Earnings	Output
Direct Impacts	59	$4	$4
Indirect Impacts	539	$31	$126
Induced Impacts	256	$10	$30
Total Impacts	**854**	**$45**	**$160**

Source: Abt Associates analysis

15 As indicated in Schlissel et al. (2008), the cost of constructing coal-fired power plants has increased substantially over the past few years, driven by factors such as increased demand for new plants in emerging markets such as China and India. As a result, several coal plant construction projects have experienced substantial increases in cost relative to their original estimates. See also the testimony of David Schlissel of Synapse Energy Economics, Inc. in the SCC case proceedings.

The results indicate that Plant operations will sustain annually approximately 854 new jobs in Virginia (including 196 in the mining sector), $45 million in labor income, and approximately $160 million in economic output.

As noted above, the results of this analysis should not be interpreted as precise values, but rather, should be used as an indication of the magnitude of the potential economic impacts. Similarly, these economic impacts cannot be added together; rather, these are measurements of three different manifestations of the annual economic effects arising from Plant operations. In addition, when interpreting these operations-related impacts, it is not appropriate to extrapolate these annual impacts very far into the future given the potential for fuel price volatility and other potential changes in plant operations over time.

With respect to the estimated total employment benefits in the mining sector (196 jobs), we also attempted to assess the extent to which the production of Virginia coal for use in the plant would result in a *real* net increase in Virginia employment. Specifically, we assessed whether the recent historical profile of coal production and production capacity in Virginia indicates that coal consumed by the plant would result from *additional* coal production and related employment, or would simply *displace* existing coal production that would otherwise be sold to other buyers in the absence of the plant. A *net gain* in mining employment due to the Plant could be achieved in three possible ways: (1) via an increase in coal production at existing, active mines in Southwest Virginia; (2) via re-activation of an idled mine(s) or opening of a new mine(s) in Southwest Virginia; or, (3) by preventing the shedding of mining jobs that would otherwise be lost in, for example, a declining market for coal production in Southwest Virginia.

In 2007, the Virginia economy produced about 25 million short tons of coal, and there are approximately 256 million short tons in reserves at actively producing mines.[16] In Wise County, there are currently 72 mines, 48 of which actively producing mines, as summarized in *Table 2-4*.

Table 2-4: Number of Coal Mines in Wise County, Virginia, by operating status

Active	New Mine	Nonproducing	Temporarily Idled	Total
48	2	12	10	72

Source: Mine Safety & Health Administration, U.S. Department of Labor, 2008

The Company argues that a sufficient fuel supply exists within a 50-mile radius of the Plant and that it is developing a fuel strategy that will encourage small producers to supply coal from existing operations and by opening smaller reserves. In addition, the Company indicated in its testimony that the Plant is expected to extend the economic life and productivity of the southwest Virginia coalfields by using fuels that, but for the presence of the Plant, might never be mined (source: DVP Martin rebuttal testimony). Lacking more detailed, publicly available information on the Company's specific arrangements for procuring coal for the Plant, we did not find sufficient data or evidence to conclude that the estimated employment effects in Virginia's mining sector would not accrue as real net gains.

16 Source: National Mining Association.

3. Assessing the Economic Impact of Changes in Electricity Rates due to the Plant

Chapter Summary

This chapter of the report presents our assessment of the economic impact of changes in electricity rates due to construction and operation of the Plant on residential and non-residential ("business") customers, and in turn, on the Virginia economy. The assessment is based on changes in expenditures by these customers for electricity:

→ For residential customers, the economic impact is based on changes in the profile of consumers' expenditures for goods and services from businesses in Virginia in response to higher rates.

→ For business customers, the economic impact is based on the pass-through of changes in electricity costs to the customers of the affected businesses and resulting changes in economic activity in Virginia.

The assessment of the rate impact includes the direct effect on electricity rates from operation of the Plant – i.e., the recovery of, and return on, the capital investment in the Virginia City Plant, and the cost of energy and other expenses for plant operation and maintenance – and the offset cost effect of the avoided cost of purchased power presumed to be displaced by generation from the Plant.

These analyses also include a policy case in which the electricity generated by the Plant, and the displaced electricity purchases, are assigned an additional cost due to a likely carbon emissions regulation. Given the likelihood that the federal government will implement carbon emissions regulation within the next few years *and further*, the potential for significant costs to the Plant under such a program, we view this assessment as highly important for understanding the probable impact of the Plant on the Virginia economy.

As the final part of this section, we bring together the estimated economic impact of the rate effect with the estimated economic impact of Plant construction and operation, as developed in *Chapter 2*, to yield a total ongoing economic impact to Virginia of the Plant. We report the findings from these analyses in terms of the net change in value of economic output, employment, and employee earnings in Virginia for 2012, 2018, and 2025.[17]

Our analysis finds that the Plant is likely to cause a *relatively* small net gain to the Virginia economy *in the absence of a carbon management program.* However, with a future carbon emissions regulatory program – which we judge as highly likely – our analysis shows that the net positive effects of the Plant are substantially diminished and lead to a loss in the Virginia economy under the *mid-permit cost* regulation case for all analysis years.

17 Year 2012 is the first year of Plant operation. Year 2018 is the sixth year of Plant operation. In its presentations before the SCC, the Company presentations indicated that the all-in cost for the Plant would approximately break even with the avoided cost of purchased power in the sixth year of operation, under the original $1.6 billion construction cost estimate – which is the reason we selected the sixth operating year as one of the years on which our analysis focused. Year 2025 was selected as an additional year sufficiently far into the future to capture rate and economic impacts due to decline in rate base and other changes in the cost of purchased power and carbon emissions regulatory program cost.

3.1 Estimating the Total Rate Effect to Virginia Ratepayers from the Virginia City Plant

Assessing the impact of rate changes necessarily begins from an estimate of the rate effect from construction and operation of the Virginia City Plant. We estimated the rate effect in two broad conceptual steps:

1. Without considering the possible rate cons

2. Including the cost of carbon emissions regulation

Estimating the Rate Effect before Consideration of Carbon Emissions Regulation

Because the case record leading to approval of the Virginia City plant does not appear to include, at least as public information, a detailed assessment of the Plant's expected rate impact once the Plant goes into rate base, we developed our own estimate of the Plant's rate effect. Inevitably, our estimate will differ from an estimate rendered by DVP; however, we expect that our estimate will not diverge by a large degree from the Company's assessment.

Key elements underlying the *capital recovery component* of this estimate are as follows:

→ Based on the revised $1.8 billion estimate of the plant's construction cost. We also estimated the "all-in" cost and rate effect for the earlier $1.6 billion estimate and used information from this assessment to develop the estimate for the $1.8 billion cost.

→ Assigned the full $1.8 billion value to the DVP rate base upon the beginning of plant operation in 2012.

→ Assumed that the capital outlay would be recovered in rates on a straight-line basis over 30 years. We couldn't find a specific proposed rate base recovery period in the case record. Given the cited plant service life of "50 or more years" (source: DVP Martin testimony), we concluded that a lengthy recovery period averaging at least 30 years for the plant's asset base would be appropriate for the analysis.

→ Assumed a total pre-tax cost of capital of 12.97 percent, based on the allowed equity rate of return of 12.12 percent (source: Final Order) and other cost of capital build-up information (sources: SCC Pate testimony and DVP Bolton). Applied this cost of capital to the average "over-the-year" rate base value remaining in a given cost recovery year after deduction of the cumulative rate base recovery values from prior years since placing the Plant into rate base.

→ Allocated 77.8 percent of the rate base value to Virginia customers of DVP (source: SCC Pate testimony). We later assumed that this same percentage of the Plant's electricity production would be purchased by Virginia customers.

→ The above factors yield a first-year capital recovery value (including cost of capital return) of $289 million or approximately $63 per MWh, based on the reported 585 MW available capacity and 90 percent capacity utilization rate (source: DVP Martin testimony). Of the total $290 million capital recovery value, approximately $225 million is allocated to Virginia customers of DVP.

Key elements underlying the *energy and other expenses* component of this estimate are as follows:

→ Assumed a first-year energy and variable O&M cost to the Plant of $1.75 per MMBtu energy input, with a heat rate of approximately 10,000 Btu per kWh (source: DVP Martin testimony). Together, these values yield a first-year energy and O&M cost of electricity of $17.50 per MWh of net energy generated.

→ Assumed that energy and variable O&M cost would change over time at the year-to-year rates estimated and reported by the U.S. Department of Energy in the *Annual Energy Outlook – 2008* for coal fuel prices (for electricity generation) in the Southeastern Electricity Reliability Council (SERC) region, the North American Electric Reliability Corporation (NERC) region in which most of DVP's generating units are located. DOE reports these values on a constant dollar (inflation-adjusted) basis. We combined these constant dollar year-to-year rates of change with a general inflation adjustment factor of 2.4 percent, which is the average of year-to-year changes in the GDP Deflator from 1990 to 2007, to yield a nominal year-to-year change in energy and variable O&M costs. The resulting changes over time are quite modest, with the total estimated change from the first year of operation, 2012, to the fifth year of operation, 2017, of 6.9 percent.

→ Estimated an additional plant expense of approximately $25 per MWh of net energy generated. This additional value is required to "true up" the total first-year "all-in" cost – *at the original $1.6 billion capital cost* – to the reported value of approximately $99 per MWh (source: DVP Martin testimony).[18] We escalated this value using the general inflation adjustment factor of 2.4 percent per year to estimate future cost values for the plant.

→ At the reported 90 percent capacity utilization rate for the plant (source: DVP Martin testimony) and the assumed assignment of 77.8 percent of the Plant's output to Virginia customers, these values yield a total cost of energy and other expenses to Virginia ratepayers of approximately $153 million in the first year of operation.

Combining the capital recovery and energy/other expenses rate components yields a total cost to Virginia ratepayers of approximately $378 million in the Plant's first year of operation – before accounting for (1) the avoided cost of purchased power otherwise purchased to meet DVP load and/or (2) the potential cost of a likely carbon emissions regulation. On a per MWh basis, this cost amounts to approximately $105 per MWh in the first year of operation, or approximately 6 percent higher than the first-year "all-in" cost of $99 per MWh reported by the Company for the earlier $1.6 billion cost estimate.

To properly assess the net cost of the Plant to Virginia ratepayers, it is necessary to account for the cost of purchased power that will be displaced by the Plant's electricity generation ("avoided cost"). Our assessment of the avoided cost involved the following elements:

→ Assumed a first-year displaced power cost of $75 per MWh, as reported in Company testimony (source: DVP Martin testimony).

→ Escalated this value at the year-to-year rates estimated and reported by the U.S. Department of Energy in the *Annual Energy Outlook – 2008* for the overall price of electricity generated in the Mid-Atlantic Area Reliability Council (MAAC) region[19] over the period of the Plant's operation. MAAC is the NERC region that contains the PJM Interconnection regional transmission organization, the electricity generation market region on which DVP primarily relies for its wholesale power purchases (source: Post-Hearing Brief of Virginia Power). As described above, DOE reports AEO forecast values on a constant dollar (inflation-adjusted) basis. We combined the constant dollar year-to-year rates of change with the general inflation adjustment factor of 2.4 percent per year to yield a nominal year-to-year change in purchased power costs. From this analysis, the cost of purchased power increases by a total of 11.7 percent over the first five years of Plant operation, or an approximate compound annual growth rate (CAGR) of approximately 2.2 percent. This estimated growth rate in the price of purchased power is less than the Company's hypothesized annual growth rate of 3 percent for the cost of purchase power (source: DVP Martin testimony).

Including the avoided cost of purchased power in the rate calculation yields a *net* cost to Virginia ratepayers from the Virginia City Plant of approximately $109 million, or $30 per MWh, in the Plant's first year of operation.

Accounting for the various changing components of the total rate effect – decline over time in the rate base component of the Plant's total rate effect, increase in energy and O&M costs, increase in purchased power costs – the *net* total cost to Virginia ratepayers declines over time. From our analysis, the net cost to Virginia ratepayers would decline to approximately $50 million, or $14 per MWh, in the sixth year of the plant's operation. The Company's presentations indicated that the all-in cost for the Plant would approximately break even with the avoided cost of purchased power in the *sixth* year of operation, under the original $1.6 billion construction cost estimate – which is the reason we selected the sixth operating year as one of the years on which our analysis focused. By 2025, the net cost becomes negative (a net rate reduction), with a total rate effect to Virginia ratepayers of approximately -$15 million or -$4 per MWh.

18 We aren't certain what expenses comprise this value. The value would include additional fixed annual expenses for plant operation and main tenance, which could be significant, property tax, and other outlays that don't vary with the production of net sellable electricity from the plant. Regardless of the uncertain aspect of this value, the resulting total cost for electric power generation from the plant matches the "all-in" cost reported by the Company.

19 The MAAC region no longer operates as a separate, stand-along reliability management region; it was absorbed into the ReliabilityFirst Corporation (RFC) region at the beginning of 2006. DOE continues to report electricity market information and forecasts in the NERC region framework that existed before 2006.

Table 3-1 summarizes the total rate effect of the Plant for 2012, 2018, and 2025. Note that these cost effects do not account for the cost of carbon emissions regulation, which is considered in the next section.

Table 3-1: Estimated Total Rate Effect of Virginia City Plant to Virginia Ratepayers

Before consideration of the cost impact of carbon emissions regulation

	Impact Analysis Year		
	2012	**2018**	**2025**
Total Rate Effect to Virginia Ratepayers ($ million, current dollars)			
Capital Recovery	$225	$189	$147
Energy & Variable O&M	$63	$67	$78
Other Expenses	$90	$104	$122
Total before Purchased Power Cost Offset	$378	$360	$347
Less Purchased Power Cost Offset	$269	$310	$361
Rate Effect per MWh Net Energy Generated ($ per MWh)			
Capital Recovery	$63	$53	$41
Energy & Variable O&M	$18	$19	$22
Other Expenses	$25	$29	$34
Total before Purchased Power Cost Offset	$105	$100	$97
Less Purchased Power Cost Offset	$75	$86	$101
Net Rate Impact	$30	$14	-$4

Source: Abt Associates analysis

Including the Cost of Carbon Emissions Regulation

In view of well-recognized concerns over global climate change, a number of federal legislative proposals have been presented that would limit carbon-dioxide and other significant greenhouse gas emissions (collectively "carbon" emissions) from emission sources such as the Virginia City Plant. In addition, the newly elected presidential administration has also indicated its commitment to limiting carbon emissions. The final structure of an eventual carbon emissions regulation cannot be known at this time, but it appears very likely that some form of a "declining cap and trade" emissions permit program and/or a carbon emissions tax will be implemented in the next few years. Under such a program, major emission sources such as the Virginia City Plant would incur additional costs to continue to emit carbon at uncontrolled levels and/or to implement carbon emissions control technology. These emission permit/tax and/or emission control costs will add directly to the Plant's costs and will increase the cost to Virginia ratepayers for electricity generated by the Plant. Because coal has the highest carbon-content among electric power sources, the additional cost burden from carbon emissions regulation would likely be substantial for the Virginia City plant and would add considerably to the Plant's cost to Virginia ratepayers.

Given the high likelihood of a federal program to limit carbon emissions and the potential for a substantial increase in the Virginia City Plant's electricity production costs, we estimated the possible costs of such a program to the Plant and included the resulting rate effect in our analysis of the economic impact of the Plant on the Virginia economy. We included this impact in our analysis as an additional cost for power generation that results from the required purchase of carbon emissions permits or payment of a carbon emissions tax. We considered assessing the cost of Carbon Capture and Storage (CCS) technology as an add-on to the Plant's capital and operating costs, but given the high uncertainty on the timing, cost, and availability of a commercially viable CCS technology, we restricted our analysis to an assessment of the potential cost effects of carbon emission permits.

We derived our estimates of the possible costs of carbon emissions regulation from a review of modeling analyses recently undertaken for the Lieberman-Warner Climate Security Act of 2008 (S 3036).[20] These analyses include efforts by:

20 Abt Associates performed a detailed review of the U.S. Environmental Protection Agency, Office of Atmospheric Programs analyses. Information on the other analyses is drawn from a compilation of analyses published by the Pew Center on Global Climate Change (*Insights from Modeling Analyses of the Lieberman-Warner Climate Security Act (S. 2191)*, May 2008).

→ U.S. Environmental Protection Agency, Office of Atmospheric Programs

→ U.S. Department of Energy, Energy Information Administration

→ American Council for Capital Formation and the National Association of Manufacturers

→ Clean Air Task Force

→ Massachusetts Institute of Technology

→ CRA International.

These analyses report estimated prices for emission permits over time, under a range of plausible scenarios defined in terms of:

→ Structure of the overall emissions management program and permit allocation framework

→ Mix of energy production technologies deployed to meet U.S. energy demand

→ The timing and cost of commercially viable carbon capture and storage technology

→ Changes in energy efficiency over time in key affected economic sectors.

These analyses indicate near-term carbon emission permit values that fall in a low-range cluster of about $23 per ton of CO_2-equivalent emissions (2012$), a mid-range cluster of about $39 per ton (2012$), and with high-range values of about $57 per ton (2012$). In addition, these analyses indicate that emission permit prices will grow substantially over time. In constant dollar terms, the near-term growth in permit prices from these studies averages 6.3 percent, or in nominal dollar terms, about 8.8 percent.

From this review, we developed two cases for our analysis of the economic impact of the Virginia City Plant:

1. A “low” impact cas $_2$-equivalent emissions in 2012, with an annual growth in nominal permit prices of 8.8 percent (*Low Permit Cost* case).

2. A “medi 8.8 percent (*Mid Permit Cost* case).[21]

For both cases, we assumed that 50 percent of the Plant’s carbon emissions would be subject to the emission permit price in 2012 and for the life of the analysis – i.e., the emission permits for these emissions will need to be purchased at auction with permits for the remainder of the Plant’s emissions being granted under an initial allocation. The assumed “emissions coverage” of the Plant’s carbon emissions is a key factor in assessing the expected impact of carbon emissions regulation on the Plant’s production costs and resulting rate effects. The recent legislative proposals grant an initial endowment of permits that would cover a substantial fraction (approximately 25 percent under Lieberman-Warner) of baseline emissions from existing emission sources. The fraction of permits that would need to be acquired at auction would then increase over time. However, recent policy discussion in the context of the presidential campaign focused on the possibility that *all* permits would be auctioned from the outset of a program. Given the substantial uncertainty in this key policy term, we adopted a “mid-range” assumption that 50 percent of the Plant’s carbon emissions – and therefore electricity generation – would incur the emission permit cost.

Other elements of the carbon emissions regulation analysis include:

→ Assumed a total of 5,368,678 tons of CO_2 would be emitted by the Plant annually (source: Norwood testimony). Based on the Plant’s expected annual net generation (4,612,140 MWh), the Plant will emit 1.16 tons of CO_2 per MWh of net energy generated.

→ Carbon emissions regulation will also affect the electricity production costs of the suppliers of DVP’s purchased power. However, the extent of that effect will depend on the carbon emissions intensity of the purchased power. We assigned

21 It would have been possible to develop a “high” impact case using the high-range permit price values. However, we were concerned that such a high price would be substantially less likely to occur, and thus would not represent as *realistic* an analysis of potential impacts as do the low and medium impact cases.

a carbon emissions intensity to purchased power based on the average carbon emissions per MWh of net generation reported by the Department of Energy for the Mid-Atlantic Area Reliability Council (MAAC) region. As described above, MAAC is the NERC region that includes the PJM Interconnection regional transmission organization – DVP's chief supplier of purchased power. For MAAC, DOE projects an average carbon emissions intensity of approximately 0.50 tons of CO_2 per MWh over the period 2012-2025. Because the MAAC carbon emissions intensity is less than the estimated coal-only intensity of 1.16 tons per MWh for the Virginia City Plant, the add-on to the price of purchased power is less than the add-on to the Plant's generating cost.

→ Consistent with the assumption that 50 percent of the Plant's electricity generation would be subject to the permit cost, we also assumed that 50 percent of the purchased power would be subject to the carbon emissions permit cost.

Accounting for the cost of carbon emissions regulation substantially increases the total estimated cost of electricity from the Virginia City Plant and the resulting net rate impact to Virginia ratepayers. *Table 3-2* summarizes the cost impact of carbon emissions regulation, as outlined above. As shown in *Table 3-2*, the carbon emissions program increases costs by a large amount in the three analysis years, for both the Low Permit Cost and Mid Permit Cost cases. And the burden increases over time with the expected increase in carbon emissions permit prices. Under the Low Permit Cost case, the total estimated rate effect to Virginia ratepayers increases by $27 million in 2012 ($136 million less $109 million), $45 million in 2018, and $82 million in 2025. Under the Mid Permit Cost case, the impact is substantially larger: an increase of $68 million in total rate effect in 2012, $112 million in 2028, and $202 million in 2025. Importantly, the Plant does not *break even* in terms of the net cost impact with accounting for purchased power offset during the period of analysis. As will be examined in later sections of this report, the likely promulgation of carbon emissions regulation substantially increases the likelihood that construction and operation of the Plant will create a material economic drag on the Virginia economy.

Table 3-2: Estimated Total Rate Effect of Virginia City Plant to Virginia Ratepayers – with consideration of Carbon Emissions Regulation

	Impact Analysis Year								
	2012	2018	2025	2012	2018	2025	2012	2018	2025
Rate Impact Analysis Case	**No Carbon Emissions Program**			**Carbon Emissions Program – Low Permit Cost**			**Carbon Emissions Program – Mid Permit Cost**		
Total Rate Impact to Virginia Ratepayers ($ million)									
Capital Recovery	$225	$189	$147	$225	$189	$147	$225	$189	$147
Energy & Variable O&M	$63	$67	$78	$63	$67	$78	$63	$67	$78
Other Expenses	$90	$104	$122	$90	$104	$122	$90	$104	$122
Carbon Emissions Regulation	$0	$0	$0	$48	$80	$143	$119	$197	$355
Total before Purchased Power Cost Offset	$378	$360	$347	$426	$439	$490	$497	$557	$702
less Purchased Power Cost Offset	$269	$310	$361	$290	$345	$423	$320	$395	$514
Net Rate Impact	$109	$50	-$15	$136	$95	$67	$177	$162	$188
Cost per MWh Net Energy Generated ($ per MWh)									
Capital Recovery	$63	$53	$41	$63	$53	$41	$63	$53	$41
Energy & Variable O&M	$18	$19	$22	$18	$19	$22	$18	$19	$22
Other Expenses	$25	$29	$34	$25	$29	$34	$25	$29	$34
Carbon Emissions Regulation	$0	$0	$0	$13	$22	$40	$33	$55	$99
Total before Purchased Power Cost Offset	$105	$100	$97	$119	$122	$137	$138	$155	$196
less Purchased Power Cost Offset	$75	$86	$101	$81	$96	$118	$89	$110	$143
Net Rate Impact	$30	$14	-$4	$38	$26	$19	$49	$45	$52

Source: Abt Associates analysis

3.2 Allocating Plant Costs to Virginia Ratepayers

As the next step in assessing the economic impact of the changes in electricity rates, we allocated the total rate effect for Virginia ratepayers between residential and non-residential ("business") consumers, and within the business consumers, over the affected economic sectors.

Allocation of the rate effect between residential and non-residential ("business") consumers involved the following elements:

→ Allocated the Virginia-only capital recovery value among broad customer classes based on reported demand factors by rate schedule, as follows: 54.0 percent to residential, 44.4 percent to non-residential "business" (sum of rate schedules GS-1, GS-2, GS-3, and GS-4) (including government and other non-business institutions), and 1.6 percent to non-residential "other" (remaining rate schedules) (source: DVP Swanson testimony).

→ Allocated the remaining elements of the total rate effect – energy and variable O&M, other expenses, and purchased power cost offset – on the basis of reported energy consumption within the above rate schedule categories: 45.2 percent to residential, 53.6 percent to non-residential "business", and 1.3 percent to non-residential "other" (source: DVP Swanson testimony).

→ Assumed that this distribution profile would remain constant over the analysis period.

→ In the subsequent economic impact analyses, we ignored the potential impact of rate changes on the non-residential "other" consumer class.

Table 3-3, below, summarizes this distribution of the total rate effect for the impact cases outlined in *Table 3-2*, above. As reported in *Table 3-3*, we expect that the distribution of the total rate effect will not be constant over time or by rate impact case. In general, the residential class absorbs a greater share of the capital recovery component of the rate effect – which is distributed in proportion to customer class contribution to demand. The business class absorbs a greater share of the energy, other expense, and purchased power offset components – which we distributed in proportion to energy consumption. These differences in allocation concepts, together with the expectation that the value of the rate components will change differentially over time, result in the varying profile of the total rate effect as shown in *Table 3-3*.

Table 3-3: Allocation of Total Virginia Rate Effect to Broad Customer Categories

	Impact Analysis Year								
	2012	2018	2025	2012	2018	2025	2012	2018	2025
Rate Impact Analysis Case	No Carbon Emissions Program			Carbon Emissions Program – Low Permit Cost			Carbon Emissions Program – Mid Permit Cost		
Total Rate Impact, net of purchased power offset (from Table 3 2, above)	$109	$50	-$15	$136	$95	$67	$177	$162	$188
Residential	$69	$39	$6	$81	$60	$43	$100	$90	$98
Business	$38	$9	-$21	$52	$33	$22	$74	$69	$87
Non-Residential Other	$2	$1	$0	$2	$2	$1	$3	$3	$3

Source: Abt Associates analysis

3.3 Estimating the Economic Impact of Rate Changes to Residential Customers

We estimated the economic impact of rate changes to residential customers, and in turn, the broader Virginia economy using two principal steps:

1. Allocating the total residential custome

2. Estimati

Allocating the Residential Customer Rate Effect Over Affected Business Sectors

The assessment of economic impacts arising from rate changes to DVP's residential customers necessarily begins with the *total rate impact values* for the residential sector reported above in *Table 3-3*, which represent nine distinct analysis cases. As described previously in *Section 3.1*, the *total rate impact values* in *Table 3-3* reflect a range of cases that consider:

→ The direct effect on electricity rates from operation of the Virginia City Plant – i.e., the recovery of, and return on, the capital investment in the Virginia City Plant, and the cost of energy and other expenses for plant operation and maintenance;

→ The offset cost effect of the avoided cost of purchased power presumed to be displaced by electricity generated by the Plant; and,

→ Policy cases in which the electricity generated by the Virginia City plant, and the displaced electricity purchases to meet DVP supply requirements, are assigned an additional cost due to a likely carbon emissions regulation.

We allocated the total residential customer rate effect to affected sectors in proportion to estimated levels of personal consumption expenditures (PCE) by consumers in Virginia. The distribution of PCE in Virginia across economic sectors is reported in the JEDI-coal modeling framework. The values reported in JEDI represent average PCE, by sector, across all household income classes in Virginia and were derived from IMPLAN 2006 data. In using this allocation concept, this analysis assumes that the residential rate effect is absorbed by residential customers as an increase in PCE for utility services, which in turn is offset by a proportionally allocated decrease in all other categories of PCE.

Table 3-4 presents a summary of the primary impact sectors for this analysis, based on the profile of PCE by consumers in Virginia, along with the proportionally allocated decrease in purchases from those sectors for each of the nine analysis cases.

Table 3-4: Allocation of Residential Customer Rate Effect to Primary Impact Sectors

		Impact Analysis Year and Rate Impact Case								
($ million)		2012	2018	2025	2012	2018	2025	2012	2018	2025
		No Carbon Emissions Program			Carbon Emissions Program – Low Permit Cost			Carbon Emissions Program – Mid Permit Cost		
Total Residential Rate Impact		$69	$39	$6	$81	$60	$43	$100	$90	$98
Key Impact Sector	**PCE (%)**	**Change in Consumers' Personal Consumption Expenditures (PCE)**								
Miscellaneous Services	35.3%	-$24	-$14	-$2	-$29	-$21	-$15	-$35	-$32	-$35
Manufacturing	23.3%	-$16	-$9	-$1	-$19	-$14	-$10	-$23	-$21	-$23
Retail Trade	13.7%	-$9	-$5	-$1	-$11	-$8	-$6	-$14	-$12	-$13
FIRE[a]	12.4%	-$9	-$5	-$1	-$10	-$7	-$5	-$12	-$11	-$12
TCPU[b]	7.5%	-$5	-$3	-$0	-$6	-$4	-$3	-$7	-$7	-$7
Wholesale Trade	4.9%	-$3	-$2	-$0	-$4	-$3	-$2	-$5	-$4	-$5
Other[c]	2.9%	-$2	-$1	-$0	-$2	-$2	-$1	-$3	-$3	-$3
Total Change in PCE	**100%**	**-$69**	**-$39**	**-$6**	**-$81**	**-$60**	**-$43**	**-$100**	**-$90**	**-$98**

[a] Includes finance, information, and real estate
[b] Includes transportation, communication, and public utilities
[c] Includes agriculture, mining, construction, and professional and government services
Source: Abt Associates analysis

Estimating the Economic Impact in the Affected Business Sectors

The total economic impact in affected business sectors due to the residential rate effect considers (1) the effect of offsetting changes in the profile of consumers' expenditures for goods and services in response to higher electricity prices (i.e., *Table 3-4*), and (2) the extent to which these offsetting changes affect economic activity in Virginia.

We estimated the total economic impact in affected business sectors using the IMPLAN input-output multipliers for Virginia present in the JEDI modeling framework. We report the findings from this analysis in terms of the total change (i.e., direct, indirect, and induced) in value of economic output (Gross State Product - GSP), employment, and employee income in Virginia.

Table 3-5 reports the results of this analysis.

Table 3-5: Allocation of Residential Customer Rate Effect to Primary Impact Sectors

	Impact Analysis Year								
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	No Carbon Emissions Regulation			**Carbon Emissions Regulation –** *Low Permit Cost*			**Carbon Emissions Regulation –** *Mid Permit Cost*		
GSP	-$111	-$63	-$10	-$131	-$96	-$70	-$160	-$144	-$157
Employment (jobs)	-948	-536	-88	-1,117	-817	-593	-1,368	-1,232	-1,341
Earnings	-$37	-$21	-$3	-$43	-$31	-$23	-$53	-$47	-$52

Source: Abt Associates analysis

3.4 Estimating the Economic Impact of Rate Changes to Business Customers

Assessing the economic impact of rate changes to business customers involves three principal steps:

1. Allocating the total business customer effect over a

2. Estimating the change in economic activity in primary i

3. Estimating the total economic imp

Allocating the Business Customer Rate Effect Over Affected Business Sectors

Table 3-3, above, summarized the allocation of the total rate effect between residential and business customers. As the first step in analyzing the impact of the rate effect to business customers, we allocated the aggregate business customer rate effect among the economic sectors that would be initially affected by the rate changes due to the Virginia City Plant. This allocation is needed to support assessment of the impact on GSP, employment and employee earnings from the change in rates to the affected business sectors.

We allocated the total business customer rate effect to affected sectors in proportion to estimated levels of electricity consumption for economic sectors in Virginia. The electricity consumption profile by economic sectors is based on the estimated electricity consumption intensity (electricity consumption in relation to Value Added) for the affected sectors and state-level Value Added in these sectors as reported by the Bureau of Economic Analysis of the U.S. Department of Commerce.

We developed the estimates of electricity consumption intensity using electricity consumption data at the state and national level by economic sector from several sources. These data sources include:

→ The Manufacturing Energy Consumption Survey, compiled by the U.S. Department of Energy, Energy Information Administration, which reports energy consumption, including consumption of purchased electricity, at approximately the level of 3-digit North American Industrial Classification System (NAICS) sectors for manufacturing sectors.

→ The State Energy Data System, also compiled by the U.S. Department of Energy, Energy Information Administration, which reports electricity and other energy consumption by state for aggregate sectors – commercial sector, industrial sector, transportation sector, and electric power sector.

→ The Economic Census, which reports electricity consumption data for the construction, mining and industrial sectors.

We combined the electricity consumption data with Value Added data from the Bureau of Economic Analysis to calculate electricity consumption intensity (MWh per million dollars of value added) for key sectors. Where necessary, we disaggregated the estimates of electricity consumption and resulting electricity consumption intensity to approximately the level of 3-digit NAICS sectors. For the manufacturing sectors, the electricity consumption intensity values are national level by sector. For the commercial, mining and construction sectors, the electricity consumption intensity values are state-level and specific to Virginia.

To estimate electricity consumption by economic sector for Virginia, we multiplied the sector-level electricity intensity values by sector-level value added for Virginia. Before performing this multiplication, we adjusted the sector-level values of value added to approximately 2012 based on the relative rates of growth of these sectors in Virginia over the past 10 years, with certain professional judgment-based adjustments to reflect the current and projected weakness of the national economy. These calculations yield estimates of electricity consumption by sector, at approximately the 3-digit NAICS level, for Virginia.

As the final step of this part of the analysis, we allocated the total business customer rate effect, as summarized in *Table 3-3*, over the primary impact sectors in proportion to the estimated electricity consumption values, by sector, for the Plant's first operating year, 2012. We adjusted these sector level allocations for years beyond 2012 based on the relative growth in value added for the *aggregate* manufacturing, commercial, mining, construction, and transportation sectors over the 10-year period, 1997-2007: that is, the individual 3-digit NAICS subsectors of the aggregate manufacturing sector were assumed to grow at the overall growth rate for the manufacturing sector, and likewise for the individual 3-digit NAICS subsectors of the aggregate commercial sector. As a result of these projections, the commercial sector's share of total business electricity consumption (and hence the estimate business customer rate effect) increases modestly over time, while the shares of the manufacturing, construction, and mining sectors decline. *Table 3-6* summarizes the resulting allocation of the total business customer rate effect to economic sectors by rate impact case and analysis year.

Table 3-6: Allocation of Total Business Customer Rate Effect by Rate Impact Case and Year

		Impact Analysis Year and Rate Impact Analysis Case								
		2012	2018	2025	2012	2018	2025	2012	2018	2025
all dollar values in $ million, nominal	Allocation 2012	No Carbon Emissions Program			Carbon Emissions Program – Low Permit Cost			Carbon Emissions Program – Mid Permit Cost		
Total Business Sector Rate Effect		**$37.6**	**$9.2**	**-$21.3**	**$52.3**	**$33.5**	**$22.5**	**$74.0**	**$69.4**	**$87.1**
Allocation to Business Sectors										
Commercial Sectors										
Wholesale trade	3.7%	$1.4	$0.4	-$0.8	$1.9	$1.3	$0.9	$2.7	$2.6	$3.5
Retail trade	5.9%	$2.2	$0.6	-$1.4	$3.1	$2.1	$1.4	$4.4	$4.3	$5.6
Information	6.0%	$2.3	$0.6	-$1.4	$3.1	$2.1	$1.5	$4.4	$4.3	$5.7
Finance and insurance	5.4%	$2.0	$0.5	-$1.3	$2.8	$1.9	$1.3	$4.0	$3.9	$5.1
Real estate, rental and leasing	10.6%	$4.0	$1.0	-$2.4	$5.5	$3.7	$2.6	$7.8	$7.7	$10.0
Professional/technical services	11.3%	$4.3	$1.1	-$2.6	$5.9	$4.0	$2.8	$8.4	$8.2	$10.7
Management of companies and enterprises	1.6%	$0.6	$0.1	-$0.4	$0.8	$0.5	$0.4	$1.2	$1.1	$1.5
Administrative and waste services	2.1%	$0.8	$0.2	-$0.5	$1.1	$0.7	$0.5	$1.6	$1.5	$2.0
Educational services	0.5%	$0.2	$0.1	-$0.1	$0.3	$0.2	$0.1	$0.4	$0.4	$0.5
Health care, social assistance	4.3%	$1.6	$0.4	-$1.0	$2.3	$1.5	$1.1	$3.2	$3.1	$4.1
Arts, entertainment, recreation	0.4%	$0.2	$0.0	-$0.1	$0.2	$0.1	$0.1	$0.3	$0.3	$0.4
Accommodation, food services	1.9%	$0.7	$0.2	-$0.4	$1.0	$0.6	$0.5	$1.4	$1.3	$1.8
Other services, except government	1.8%	$0.7	$0.2	-$0.4	$1.0	$0.6	$0.4	$1.4	$1.3	$1.7
Government	12.8%	$4.8	$1.2	-$2.9	$6.7	$4.4	$3.1	$9.4	$9.2	$12.1
Total Commercial	**68.4%**	**$25.7**	**$6.5**	**-$15.8**	**$35.8**	**$23.8**	**$16.7**	**$50.6**	**$49.4**	**$64.7**
Manufacturing Sectors										
Food, beverage, and tobacco	6.3%	$2.4	$0.5	-$1.1	$3.3	$1.9	$1.2	$4.7	$4.0	$4.6
Textile mills and products	1.5%	$0.6	$0.1	-$0.3	$0.8	$0.5	$0.3	$1.1	$0.9	$1.1
Apparel and leather products	0.0%	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Wood products	1.3%	$0.5	$0.1	-$0.2	$0.7	$0.4	$0.2	$1.0	$0.8	$0.9
Paper	2.2%	$0.8	$0.2	-$0.4	$1.2	$0.7	$0.4	$1.6	$1.4	$1.6
Printing and related support	0.5%	$0.2	$0.0	-$0.1	$0.3	$0.2	$0.1	$0.4	$0.3	$0.4
Petroleum and coal products	0.1%	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Chemicals	2.3%	$0.9	$0.2	-$0.4	$1.2	$0.7	$0.4	$1.7	$1.5	$1.7
Plastics and rubber products	2.6%	$1.0	$0.2	-$0.5	$1.3	$0.8	$0.5	$1.9	$1.6	$1.9
Nonmetallic mineral products	1.1%	$0.4	$0.1	-$0.2	$0.6	$0.3	$0.2	$0.8	$0.7	$0.8
Primary metals	1.8%	$0.7	$0.2	-$0.3	$1.0	$0.6	$0.3	$1.4	$1.2	$1.3
Fabricated metal products	1.4%	$0.5	$0.1	-$0.3	$0.7	$0.4	$0.3	$1.0	$0.9	$1.0
Machinery	0.7%	$0.3	$0.1	-$0.1	$0.4	$0.2	$0.1	$0.5	$0.5	$0.5
Computer, electronic products	1.6%	$0.6	$0.1	-$0.3	$0.8	$0.5	$0.3	$1.2	$1.0	$1.1
Electrical equip, components	0.3%	$0.1	$0.0	$0.0	$0.1	$0.1	$0.0	$0.2	$0.2	$0.2
Transportation equipment	3.0%	$1.1	$0.3	-$0.5	$1.6	$0.9	$0.6	$2.2	$1.9	$2.2
Furniture and related products	0.3%	$0.1	$0.0	-$0.1	$0.2	$0.1	$0.1	$0.2	$0.2	$0.2
Miscellaneous	0.2%	$0.1	$0.0	$0.0	$0.1	$0.0	$0.0	$0.1	$0.1	$0.1
Total Manufacturing	**27.1%**	**$10.2**	**$2.3**	**-$4.8**	**$14.2**	**$8.4**	**$5.1**	**$20.0**	**$17.4**	**$19.8**
Construction	**2.3%**	**$0.9**	**$0.2**	**-$0.3**	**$1.2**	**$0.6**	**$0.3**	**$1.7**	**$1.2**	**$1.1**
Mining	**2.0%**	**$0.8**	**$0.2**	**-$0.3**	**$1.0**	**$0.6**	**$0.3**	**$1.5**	**$1.2**	**$1.3**
Transportation	**0.2%**	**$0.1**	**$0.0**	**$0.0**	**$0.1**	**$0.1**	**$0.0**	**$0.2**	**$0.2**	**$0.2**
Total Business Sectors	**100.0%**	**$37.6**	**$9.2**	**-$21.3**	**$52.3**	**$33.5**	**$22.5**	**$74.0**	**$69.4**	**$87.1**

Source: Abt Associates analysis

As shown in *Table 3-6*, the total rate effect to Virginia's business customers due to the Virginia City Plant is likely to be substantial – particularly under the Carbon Emissions Regulatory Program cases, which we judge to provide the more realistic assessment of likely rate effects. Under these cases, the aggregate rate increases to the business sectors total in the tens of millions of dollars per year. In the *mid Permit Cost* case, which we judge as a very plausible cost impact scenario, the aggregate rate increase to business customers nears $100 million by 2025. Looking at the distribution by sectors, we expect that Virginia's commercial sectors will absorb the largest share of the business customer rate effect. Among these sectors, retail trade; information; finance and insurance; real estate, rental and leasing; professional/technical services; and government will see the largest effects. Among the manufacturing sectors, food, beverage, and tobacco; plastics and rubber products; chemicals; paper; and transportation equipment will see the largest effects.

Estimating the Change in Economic Activity in Directly Affected Sectors

Our assessment of the economic impact of the business customer rate effects begins from the assumption that directly affected business customers – i.e., those customers incurring an electricity rate increase – will attempt to pass that increase along to *their* customers as price increases. As a result of these price increases, these directly affected customers are likely to see contractions in their total sales and production (*economic output*). The extent of contraction in output will depend on the expected character of the market response, which, in economic analysis, is captured in the concept of price elasticity of demand. For markets in which demand is *elastic* – i.e., markets for goods and services for which consumers are relatively sensitive to changes in price – the contraction in output will be more substantial. For markets in which demand is *inelastic* – i.e., markets for goods and services for which consumers are relatively *insensitive* to changes in price – the contraction in output will be less substantial.

To assess the impact in the directly affected business sectors, we compiled a set of demand elasticity values, which are summarized in *Table 3-7*, below. Mathematically, the elasticity value indicates the percentage change in the quantity demanded of a given product for a percent change in product price. Because the normal demand response to a price increase is a reduction in quantity demanded, elasticity values have a negative sign. For example, the indicated value of -0.50 for wholesale trade means that for a one percent increase in product prices, the quantity of wholesale trade activity would contract by *one-half percent*. Elasticity values that are closer to zero (e.g., food, beverage, and tobacco at -0.30) are indicative of inelastic demand – demand that is *less* sensitive to changes in product prices. Elasticity values that are farther from zero (e.g., accommodation, food services at -2.27) are indicative of elastic demand – demand that is *more* sensitive to changes in product prices.

Table 3-7: Price Elasticity of Demand, By Rate Impact Sector

Sector	Elasticity	Sector	Elasticity
Commercial Sectors		**Manufacturing Sectors**	
Wholesale trade	-0.50	Food, beverage, and tobacco	-0.30
Retail trade	-0.50	Textile mills and products	-0.40
Information	-0.18	Apparel and leather products	-0.70
Finance and insurance	-0.56	Wood products	-0.78
Real estate, rental and leasing	-0.55	Paper	-0.63
Professional/technical services	-0.37	Printing and related support	-0.76
Management of companies and enterprises	-0.50	Petroleum and coal products	-0.60
Administrative and waste services	-1.00	Chemicals	-0.89
Educational services	-1.10	Plastics and rubber products	-1.05
Health care, social assistance	-0.36	Nonmetallic mineral products	-0.50
Arts, entertainment, recreation	-0.69	Primary metals	-1.00
Accommodation, food services	-2.27	Fabricated metal products	-1.52
Other services, except government	-0.40	Machinery	-1.08
Government	-0.10	Computer, electronic products	-1.43
Construction	-0.45	Electrical equip, components	-0.64
Mining	-0.50	Transportation equipment	-1.17
Transportation	-1.03	Furniture and related products	-1.26
		Miscellaneous	-0.85

Source: Abt Associates compilation from multiple published sources

To apply the demand elasticity concept to estimate the change in output, we assumed that the directly affected business customers would attempt to pass on the entire direct rate effect as a price increase. Holding constant the *quantity of goods and services produced/sold in the sector* – at the outset, before calculating the demand elasticity response from the price increase – this means that the attempted percentage increase in price of the sector's goods and services will equal the total rate effect to the sector as a percentage of the total value of goods and services sold/produced in the sector (in Virginia) before the rate effect. This percentage change can then be multiplied by the sector's elasticity value to calculate the percentage change in total sector output. Further, multiplying this percentage change in total sector output by the initial total value of goods and services produced/sold in the sector (again, in Virginia) yields the *direct* economic impact of the business customer rate effect from the Virginia City Plant. In keeping with conventional economic analytic concepts and terminology for assessing the regional economic impact of economic events such as the rate effect of the Virginia City Plant, we refer to the change in output in directly affected sectors as the *direct* impact. As described in the next section, the *direct* impact will be accompanied by additional effects via transaction linkages among economic sectors. The combination of these direct and indirect/induced effects yields the *total* economic impact, which we estimate in terms of changes in output (GSP), employment and employee income.

The calculation of direct economic impact is as follows:

$$\Delta\, Output_{sector} = \left(Rate\ Effect_{sector} \Big/ Revenue_{sector} \right) x\ Elasticity_{sector}\ x\ Revenue_{sector} \qquad (1)$$

or simply

$$\Delta\, Output_{sector} = Rate\ Effect_{sector}\ x\ Elasticity_{sector} \qquad (2)$$

Table 3-8 summarizes the direct economic impact, for Virginia, calculated according to this concept by rate impact case and analysis year.

Table 3-8: Direct Economic Impact of Total Business Sector Rate Effect

	Impact Analysis Year and Rate Impact Analysis Case								
	2012	2018	2025	2012	2018	2025	2012	2018	2025
all dollar values in $ million, nominal	No Carbon Emissions Regulation			Carbon Emissions Regulation – Low Cost			Carbon Emissions Regulation – Mid Cost		
Commercial Sectors									
Wholesale trade	-$0.7	-$0.2	$0.4	-$1.0	-$0.6	-$0.4	-$1.4	-$1.3	-$1.7
Retail trade	-$1.1	-$0.3	$0.7	-$1.6	-$1.0	-$0.7	-$2.2	-$2.1	-$2.8
Information	-$0.4	-$0.1	$0.2	-$0.6	-$0.4	-$0.3	-$0.8	-$0.8	-$1.0
Finance and insurance	-$1.1	-$0.3	$0.7	-$1.6	-$1.1	-$0.7	-$2.2	-$2.2	-$2.9
Real estate, rental and leasing	-$2.2	-$0.6	$1.3	-$3.0	-$2.0	-$1.4	-$4.3	-$4.2	-$5.5
Professional/technical services	-$1.6	-$0.4	$1.0	-$2.2	-$1.5	-$1.0	-$3.1	-$3.0	-$4.0
Management of companies and enterprises	-$0.3	-$0.1	$0.2	-$0.4	-$0.3	-$0.2	-$0.6	-$0.6	-$0.7
Administrative and waste services	-$0.8	-$0.2	$0.5	-$1.1	-$0.7	-$0.5	-$1.6	-$1.5	-$2.0
Educational services	-$0.2	-$0.1	$0.1	-$0.3	-$0.2	-$0.1	-$0.4	-$0.4	-$0.5
Health care, social assistance	-$0.6	-$0.1	$0.4	-$0.8	-$0.5	-$0.4	-$1.2	-$1.1	-$1.5
Arts, entertainment, recreation	-$0.1	$0.0	$0.1	-$0.2	-$0.1	-$0.1	-$0.2	-$0.2	-$0.3
Accommodation, food services	-$1.6	-$0.4	$1.0	-$2.2	-$1.5	-$1.0	-$3.1	-$3.1	-$4.0
Other services, except government	-$0.3	-$0.1	$0.2	-$0.4	-$0.3	-$0.2	-$0.5	-$0.5	-$0.7
Government	-$0.5	-$0.1	$0.3	-$0.7	-$0.4	-$0.3	-$0.9	-$0.9	-$1.2
Total Commercial	**-$11.5**	**-$2.9**	**$7.1**	**-$16.0**	**-$10.6**	**-$7.4**	**-$22.6**	**-$22.0**	**-$28.9**
Manufacturing Sectors									
Food, beverage, and tobacco	-$0.7	-$0.2	$0.3	-$1.0	-$0.6	-$0.4	-$1.4	-$1.2	-$1.4
Textile mills and products	-$0.2	$0.0	$0.1	-$0.3	-$0.2	-$0.1	-$0.4	-$0.4	-$0.4
Apparel and leather products	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Wood products	-$0.4	-$0.1	$0.2	-$0.5	-$0.3	-$0.2	-$0.7	-$0.6	-$0.7
Paper	-$0.5	-$0.1	$0.2	-$0.7	-$0.4	-$0.3	-$1.0	-$0.9	-$1.0
Printing and related support	-$0.1	$0.0	$0.1	-$0.2	-$0.1	-$0.1	-$0.3	-$0.2	-$0.3
Petroleum and coal products	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Chemicals	-$0.8	-$0.2	$0.4	-$1.1	-$0.6	-$0.4	-$1.5	-$1.3	-$1.5
Plastics and rubber products	-$1.0	-$0.2	$0.5	-$1.4	-$0.8	-$0.5	-$2.0	-$1.7	-$2.0
Nonmetallic mineral products	-$0.2	$0.0	$0.1	-$0.3	-$0.2	-$0.1	-$0.4	-$0.3	-$0.4
Primary metals	-$0.7	-$0.2	$0.3	-$1.0	-$0.6	-$0.3	-$1.4	-$1.2	-$1.3
Fabricated metal products	-$0.8	-$0.2	$0.4	-$1.1	-$0.7	-$0.4	-$1.6	-$1.4	-$1.6
Machinery	-$0.3	-$0.1	$0.1	-$0.4	-$0.2	-$0.1	-$0.6	-$0.5	-$0.6
Computer, electronic products	-$0.8	-$0.2	$0.4	-$1.2	-$0.7	-$0.4	-$1.7	-$1.4	-$1.6
Electrical equip, components	-$0.1	$0.0	$0.0	-$0.1	-$0.1	$0.0	-$0.1	-$0.1	-$0.1
Transportation equipment	-$1.3	-$0.3	$0.6	-$1.8	-$1.1	-$0.7	-$2.6	-$2.3	-$2.6
Furniture and related products	-$0.1	$0.0	$0.1	-$0.2	-$0.1	-$0.1	-$0.3	-$0.2	-$0.3
Miscellaneous	-$0.1	$0.0	$0.0	-$0.1	$0.0	$0.0	-$0.1	-$0.1	-$0.1
Total Manufacturing	**-$8.2**	**-$1.9**	**$3.9**	**-$11.4**	**-$6.7**	**-$4.1**	**-$16.1**	**-$14.0**	**-$15.9**
Construction	**$0.9**	**$0.2**	**-$0.3**	**$1.2**	**$0.6**	**$0.3**	**$1.7**	**$1.2**	**$1.1**
Mining	**$0.8**	**$0.2**	**-$0.3**	**$1.0**	**$0.6**	**$0.3**	**$1.5**	**$1.2**	**$1.3**
Transportation	**$0.1**	**$0.0**	**$0.0**	**$0.1**	**$0.1**	**$0.0**	**$0.2**	**$0.2**	**$0.2**
Total Business Sectors	**$37.6**	**$9.2**	**-$21.3**	**$52.3**	**$33.5**	**$22.5**	**$74.0**	**$69.4**	**$87.1**

Source: Abt Associates Analysis

Estimating the Total Economic Impact of the Change in Business Customer Rates

In the same way as described in *Section 3.3* (page 2), above, we used IMPLAN input-output multipliers for Virginia to estimate the total impact (i.e., direct, indirect, and induced) on economic output (GSP), employment, and employee income in Virginia resulting from the business customer rate effect. *Table 3-9*, below, reports the results of this analysis.

Table 3-9: Total Economic Impact in Virginia Due to Business Customer Rate Changes

	Impact Analysis Year								
($ million)	2012	2018	2025	2012	2018	2025	2012	2018	2025
	No Carbon Emissions Regulation			Carbon Emissions Regulation – Low Permit Cost			Carbon Emissions Regulation – Mid Permit Cost		
Commercial Sectors									
GSP	-$33	-$8	$18	-$45	-$29	-$19	-$64	-$60	-$74
Employment (jobs)	-220	-54	126	-306	-197	-133	-433	-407	-514
Earnings	-$10	-$2	$6	-$14	-$9	-$6	-$20	-$19	-$23
Source: Abt Associates analysis									

In the following section, we combine the estimated impact from the rate increases to residential and business customers to yield our overall estimate of the economic effects of rate increases due to the Plant on the Virginia economy.

3.5 Combining the Residential and Business Customer Rate Effects

Table 3-10 reports our estimate of the total economic impact to Virginia of the rate changes to residential and business customers due to the Virginia City Plant.

Table 3-10: Total Economic Impact in Virginia Due to Business Customer Rate Changes

	Impact Analysis Year								
($ million)	2012	2018	2025	2012	2018	2025	2012	2018	2025
	No Carbon Emissions Regulation			Carbon Emissions Regulation – Low Permit Cost			Carbon Emissions Regulation – Mid Permit Cost		
Commercial Sectors									
GSP	-$144	-$71	$8	-$176	-$125	-$89	-$224	-$204	-$231
Employment (jobs)	-1,168	-590	38	-1,423	-1,014	-726	-1,801	-1,639	-1,855
Earnings	-$47	-$23	$3	-$57	-$40	-$29	-$73	-$66	-$75
Source: Abt Associates analysis									

As shown in *Table 3-10*, we estimate that the potential impact on the Virginia economy of the rate changes due to the Virginia City Plant will be quite substantial. Under the *Mid Permit Cost Carbon Emissions Regulation* case, the impact in terms of loss in GSP begins at $224 million in 2012, declines to $204 million in 2018, and increases to $231 million in 2025. The impacts are lower under the *Low Permit Cost* case, but still substantial at output losses of $176 million in 2012, $125 million in 2018, and $89 million in 2025. As we described previously, we view the carbon emissions regulation cases as providing the more realistic assessment of the expected economic outcomes from the Plant's operations.

These output impacts are accompanied by losses in jobs and employee earnings. Under the *Mid Permit Cost* carbon emissions program case, the employment loss averages 1,765 jobs over the three analysis years, and the employee income loss averages $71 million over the three years.

Of note, in its presentations before the Virginia Corporation Commission, the Company argued that the Plant would achieve a break-even point at which it would no longer impose a ratepayer burden and negative impact to the Virginia economy, but would create a net benefit, in particular, due to the increasing cost of the avoided purchased power (source: DVP Martin testimony). In *Table 3-10*, above, this projected result manifests as an increase (positive values) in output, employment and earnings in 2025 for the *No Carbon Emissions Regulation* case, compared to decreases (negative values) in 2012 and 2018. However, the Company's argument glosses over a key point: the Plant will accumulate a substantial negative balance of additional ratepayer burden in its first years of operation *before* it would achieve the projected break-even. Going forward, this accumulated ratepayer burden would not be "worked off" until the cumulative ratepayer savings in future years exceeded the accumulated ratepayer burden. Moreover, if this analysis accounts for the time value of money at a reasonable discount rate, the point in the future at which ratepayers would break even on the present value of cumulative burden and savings would be yet farther into the future than indicated by the simple undiscounted accumulation of ratepayer burdens and savings. The extension of this break-even point farther into the future in a present value analysis, results from the fact that the Plant's ratepayer benefits, if and when they occur, would be discounted more heavily because of their distance into the future compared to the ratepayer burdens, which have already begun[22] and would continue in the period immediately following inclusion of the Plant in rate base.

We have not explicitly analyzed when the *present value* break-even point would occur, but from our analyses, we expect that it could be as far as 15 years into the future.

3.6 Aggregate Economic Effects due to Ongoing Plant Operations and Changes in Electricity Rates

This section assesses the net economic effects of both economic impact mechanisms due to the Plant:

1. Econom
   Plant; and,

2. -Econom
   cover the costs associated with the Plant's construction and operation.

The economic effects due to the former mechanism were analyzed previously in *Chapter 2* and the economic effects due to the latter were analyzed in *Sections 3.1 - 3.5*.

As described in *Chapter 2*, the total construction cost of the Plant is $1.8 billion dollars, approximately $450 million of which is estimated to be spent in Virginia during the 4-year construction period. *Table 3-11* summarizes the cumulative economic impacts of Plant construction on the Virginia economy in terms of GSP, employment, and labor income, over the 4-year construction period.

Table 3-11: Summary of Economic Impacts in Virginia, during Construction Period (2008 – 2012) (millions of 2008 dollars)

	Output (GSP)	Jobs[a]	Earnings
Total Impacts [a]	$720	5,689	$419
Total Impacts, average annual	$180	1,422	$105

[a] Job impacts are full-time job-year equivalents for the 48 month construction period
Source: Abt Associates analysis

In addition, the analysis in *Chapter 2* estimated the annually recurring economic effects from operating the Plant. *Table 3-12*, below, presents the economic effects due to Plant operations in nominal terms for the three analysis years described in this report: 2012, 2018, and 2025.[23]

Table 3-12: Summary of Economic Impacts in Virginia, due to Plant Operations

($ million)	2012	2018	2025
Output (GSP)	$176	$202	$238
Employment	854	854	854
Earnings	$49	$57	$67

Source: Abt Associates analysis

22 Through collection of financing costs during the Plant's construction period, which is provided for under the SCC-approved Rider S.

23 Operations-related impacts were originally estimated in constant 2008 dollars. We converted these impacts to a nominal basis, adjusting for inflation, for comparison with the economic effects over time due to changes in electricity rates.

We estimated the aggregate net economic effects of the Plant by summing (1) the total impacts of anticipated changes in electricity rates (e.g., *Table 3-10*) and (2) the total impacts from Plant operations reported above in *Table 3-12*.[24]

Table 3-13 reports our estimated aggregate net economic effects of the Plant, accounting for both Plant operations and estimated changes in electricity rates over time.

Table 3-13: Aggregate Annual Net Economic Impacts in Virginia, due to the Plant

	Impact Analysis Year								
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	No Carbon Emissions Regulation			**Carbon Emissions Regulation – Low Permit Cost**			**Carbon Emissions Regulation – Mid Permit Cost**		
Commercial Sectors									
GSP	$32	$131	$247	-$1	$78	$149	-$48	-$1	$8
Employment (jobs)	-314	264	892	-569	-160	128	-947	-785	-1,001
Earnings	$2	$33	$70	-$8	$17	$38	-$23	-$9	-$8

Source: Abt Associates analysis

As reported in *Table 3-13*, we estimate that the Plant will contribute a net gain in economic output to the Virginia economy in each of the analysis years under the No Carbon Emissions Regulation case. The output and employment gains from the operation and maintenance of the Plant offset the near-term impact from the rate increases due to the Plant's operation. Under the two Carbon Emissions Regulation cases, however, the findings are mixed. The Plant generates a modest net loss to the Virginia economy in the early years of its operation under the Low Permit Cost case before providing net gain in later years. Under the Mid Permit Cost case, the loss to the economy continues for additional years before turning to a positive effect in the 2025 analysis year.

24 Economic impacts due to Plant construction, although substantial, are temporary and occur before the Plant begins operation in 2012. For this reason, these impacts are not added directly to the ongoing operations- and rate-related impacts

4. Assessing the Energy Efficiency Alternative

Chapter Summary

Today's significant energy challenges have stimulated renewed interest in the potential for energy efficiency and other electricity demand management opportunities to meet these challenges in ways that provide net benefits to consumers, and that are cost competitive with traditional energy supply technologies.[25]

This chapter evaluates the economic impact of meeting a quantity of electricity demand – equivalent to the output of the Plant – *via energy efficiency*, a demand-side resource. This analysis finds that reducing overall energy usage through efficiency measures in Virginia can potentially offset the need for the base load plant that is the focus of this report at a lower overall cost to Virginia ratepayers and with substantial economic benefits to Virginia. The analysis is based on two energy efficiency cost cases (low and medium), which were developed from the set of cost-effective energy efficiency opportunities in Virginia identified by ACEEE (ACEEE 2008).

The analysis presented below does not evaluate or presume to know which *specific energy efficiency policies/programs* or combinations thereof are the best options for Virginia, nor does this analysis intend to suggest that the Commonwealth consider only energy efficiency and other demand side resources for meeting future energy needs. Rather, this is an illustrative analysis that generally highlights *the relative costs* of reducing demand for energy versus increasing the supply of energy, and the potential gains from considering energy efficiency as part of a comprehensive, least-cost integrated resource planning process.

This analysis includes the same conceptual components as presented for the Plant in *Chapters 2* and *3*:

→ Assessing the impact on the Virginia economy in terms of increased output and job creation from the outlays for the Energy Efficiency Alternative

→ Assessing the impact on the Virginia economy of electricity rate changes that are presumed to accompany implementation of the Energy Efficiency Alternative.

We then combine these separate analyses to yield the total impact of the Energy Efficiency Alternative to Virginia in *Section 4.8*. We report the findings from these analyses in terms of the net change in value of economic output, employment, and employee earnings in Virginia for 2012, 2018, and 2025. Key findings of this analysis include:

→ The impact on the Virginia economy of the rate changes due to the Energy Efficiency Alternative will be substantial and, unlike the rate effect from the Plant, *uniformly beneficial* (see *Table 4-7*).

→ The aggregate net economic effects of the Energy Efficiency Alternative cases – accounting for both (1) the energy efficiency outlays and (2) the associated changes in electricity rates – are also positive and substantial for all analysis cases and years.

For example, under the *Mid Carbon-Permit Cost* case and *Mid Energy Efficiency Cost* case, the gain in GSP in Virginia is $435 million in 2012 and increases to $682 million in 2025. The output gains are accompanied by gains in jobs and employee earnings (employment increases by 3,171 in 2012 and increases further to 5,050 in 2025).

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25 See, for example, the *National Action Plan for Energy Efficiency* (EPA, 2006), produced by the U.S. EPA and DOE in collaboration with more than 60 leading energy-focused organizations (http://www.epa.gov/cleanenergy/energy-programs/napee/resources/action-plan.html).

4.1 Energy Efficiency Opportunities in Virginia

A recent study by the American Council for an Energy-Efficient Economy (ACEEE) found that substantial, cost-effective energy efficiency opportunities exist in Virginia (ACEEE, 2008).

The report, entitled *Energizing Virginia: Efficiency First*, concludes that by investing in energy-efficient technologies, the Commonwealth of Virginia can reduce its electricity needs by one-fifth; deliver cleaner, less expensive power to Virginia consumers; create thousands of new jobs; and better position the state to more cost effectively meet its future energy requirements.

A key part of ACEEE's analysis included an assessment of cost-effective opportunities to reduce electricity consumption in residential and commercial buildings, the industrial sector, and combined heat and power (CHP). This assessment included only existing technologies and practices, and a technology or practice was deemed cost-effective if its levelized cost of saved electricity is less than the average retail rate of electricity for a given customer class in Virginia (ACEEE 2008).[26] *Table 4-1*, following page, presents a summary of the cost-effective energy efficiency potential in the residential, commercial, and industrial sectors estimated by ACEEE. We ranked these measures in ascending order according to their estimated levelized cost.

Table 4-1: Energy Efficiency Potential in Virginia and Costs, by End-Use

Sector/Customer Class	End-Use	Annual Savings (GWh)	Levelized Cost ($/kWh)
Residential	Lighting	2,939	-$0.003
Industrial	Total Compressed Air	311	$0.000
Industrial	Refrigeration	84	$0.000
Commercial	Office Equipment	1,935	$0.003
Industrial	Sensors & Controls	75	$0.010
Industrial	Electric Supply	618	$0.010
Industrial	Pumps	468	$0.010
Commercial	Lighting	8,878	$0.011
Commercial	Refrigeration	796	$0.017
Industrial	Lighting	310	$0.020
Industrial	Fans	133	$0.020
Residential	Plug Loads	900	$0.021
Residential	Electricity Use Feedback	376	$0.022
Commercial	HVAC	3,993	$0.028
Industrial	Total Motors	866	$0.030
Commercial	New Buildings	3,348	$0.031
Commercial	Water Heating	228	$0.033
Residential	Furnace Fans	1,005	$0.035
Residential	HVAC	5,940	$0.043
Industrial	Duct/Pipe Insulation	663	$0.050
Residential	New Homes	949	$0.054
Industrial	Energy Information Systems	199	$0.060
Residential	Refrigeration	447	$0.060
Residential	Water Heating	1,695	$0.074
Residential	Appliances	76	$0.078
Commercial	Appliances and Other	13	$0.101
Total and Average		**37,245**	**$0.026**

Source: Abt Associates analysis, adapted from ACEEE (2008)

26 Levelized cost is the constant annual cost (in constant dollar terms) needed to recover the total investment over the life of the energy efficiency measure. It is a function of the lifetime of the measure, the cost of the measure, the annual energy savings, and an assumed inflation-adjusted discount rate of 5 percent (equivalent to approximately 7.5 percent on a nominal basis). The economic potential of each measure was estimated over an 18-year period of 2008 - 2025, and accounted for replacement costs incurred during that period for each measure.

Table 4-1 indicates the annual potential for over 37,000 GWh of cost-effective energy efficiency savings based on current electricity prices and existing efficiency technologies. This is equivalent to eight times the annual output of the Wise County plant, which is expected to generate approximately 4,600 GWh per year. However, as the ACEEE study also discusses, these opportunities may not be realized unless regulatory and other barriers to adopting efficiency policies and programs are mitigated. Broadly speaking, these barriers include (ACEEE 2008, Kushler et al. 2006):

→ Awareness of energy efficiency opportunities;

→ Principal-agent barrier, where the person making the efficiency investment does not directly benefit from the energy savings;

→ Regulatory barriers (e.g., regulation may discourage utilities from investing in energy efficiency because they cannot fully recover their costs or make an attractive return on their DSM investments);

→ Financial barriers (e.g., the private sector is traditionally inclined to do make relatively large, one-time investments rather than a larger number of relatively small investments, which is often required to broadly implement energy efficiency programs); and,

→ Expanding demand response is a challenge since most consumers don't understand demand resources and its benefits, and that it requires both utility and customer investments in new infrastructure.

Due to these barriers, it may not be reasonable to presume or expect that a majority of these opportunities can be realized in the *very near term*. But, these challenges notwithstanding, there is little doubt that the potential gains from energy efficiency in Virginia over the mid- to long-term are substantial and achievable. An array of utility-based energy efficiency policies and programs are already proving themselves in other states, delivering efficiency resources and reducing consumer electric expenditures. For example, Bonneville Power Administration (BPA) provides funding for various energy efficiency activities to distribution utilities in its service territory through the Conservation Rate Credit (CRC) and Conservation Acquisition Agreement (CAA) initiatives.[27]

The analysis presented below does not presume to evaluate or know which specific energy efficiency policies/programs or combinations thereof are the best options for Virginia, nor does this analysis intend to suggest that the Commonwealth consider only energy efficiency and other demand side resources for meeting future energy needs. Rather, this is intended to be an illustrative analysis that highlights, in a general way, the relative costs of reducing demand for energy versus increasing the supply of energy, and the potential gains from considering energy efficiency as part of a comprehensive, least-cost integrated resource planning process.

The following analysis of the Energy Efficiency Alternative includes the same conceptual components as presented in the preceding *Chapter 2: Assessing the Economic Impact of Plant Construction and Operation and Chapter 3: Assessing the Economic Impact of Changes in Electricity Rates* for the Virginia City Plant:

→ Assessing the impact on the Virginia economy in terms of increased output and job creation from the outlays for the Energy Efficiency Alternative

→ Assessing the impact on the Virginia economy of electricity rate changes that are presumed to accompany implementation of the Energy Efficiency Alternative.

Because our assessment of the increased output and job creation from the outlays for the Energy Efficiency Alternative follows from the analysis of the *concept* and *cost* of the Energy Efficiency Alternative, we invert the order of discussion from that followed for the analysis of the Plant. Specifically, we present the analysis of the rate effect first – in *Section 4.2* through *Section 4.6* – before presenting the analysis of the ongoing outlay effect, in *Section 4.7*. In *Section 4.8*, we combine these separate analyses to yield the total impact of the Energy Efficiency Alternative.

27 For more information on BPA's programs, see http://www.bpa.gov/energy/n/projects/. For additional examples, also see Kushler et al. (2006) and the Database of State Incentives for Renewables and Efficiency (DSIRE), which is a comprehensive source of information on state, local, utility, and federal incentives that promote renewable energy and energy efficiency.

4.2 Estimating the Total Rate Effect to Virginia Ratepayers from the Energy Efficiency Alternative

From our review of the ACEEE study, we developed two energy efficiency cost cases for our analysis of the economic impact of procuring an equivalent amount of energy resources as the Plant through energy efficiency:

1. -A “low” tunities in the non-residential sector, which is $0.01/kWh (or $10.10/MWh) in constant 2006 dollars. We adjusted this value to a 2012 equivalent value using a general inflation adjustment factor of 2.4 percent per year, which is the average of year-to-year changes in the GDP Deflator from 1990 to 2007. The 2012 equivalent cost value is $11.63/MWh.

   The business sector efficiency opportunities used to develop the low cost energy efficiency case are reproduced below from *Table 4-1* and represent approximately 13,600 GWh of annual potential energy savings (equivalent to about 3 times the annual output of the Plant).

Table 4-2: “Low Cost” Energy Efficiency Potential in Virginia’s Business Sectors

Sector/Customer Class	End-Use	Annual Savings (GWh)	Weighted Levelized Cost ($/kWh)
Industrial	Total Compressed Air	311	$0.000
Industrial	Refrigeration	84	$0.000
Commercial	Office Equipment	1,935	$0.003
Industrial	Sensors & Controls	75	$0.010
Industrial	Electric Supply	618	$0.010
Industrial	Pumps	468	$0.010
Commercial	Lighting	8,878	$0.011
Commercial	Refrigeration	796	$0.017
Industrial	Lighting	310	$0.020
Industrial	Fans	133	$0.020
Total		**13,608**	**$0.010**

Source: Abt Associates analysis, adapted from ACEEE (2008)

2. A “medi efficiency opportunities from *Table 4-1*, which is $0.026/kWh (or, $26.54/MWh) in constant 2006 dollars. Adjusted for inflation, this value is approximately $29.41/MWh in 2012. This cost case implicitly assumes that if utilities in Virginia were to undertake additional investments in energy efficiency then the cost of energy savings from those policies and programs would, on average, be approximately equal to the unit cost of the entire portfolio of cost-effective energy efficiency opportunities.

For both energy efficiency cost cases, we then developed an *Administrative and Marketing* add-on to account for costs that would be incurred to implement and administer the energy efficiency programs and policies. This overhead cost adder is based on the annual average energy savings and administrative costs in ACEEE’s *medium energy efficiency policy scenario* from 2011 to 2015 (ACEEE, 2008).[28]

Including program overhead costs, the resulting total unit costs of potential energy savings via energy efficiency in 2012 are estimated to be $31/MWh and $49/MWh for the low and medium energy efficiency cost cases, respectively. We assumed that these values would increase over time at the general rate of inflation used elsewhere in this analysis.

To estimate the total rate effect of each efficiency cost case to DVP’s customers, we assumed that, as part of an integrated resource planning process, the Company would directly undertake investments in energy efficiency instead of building the Plant. In other words, to avoid speculation about the configuration, incentive structure, etc., of potential efficiency programs that might be undertaken to realize these energy savings opportunities, we simply modeled the cost of energy efficiency as though the efficiency potential itself was financed by the Company with costs recovered through rates.

28 ACEEE’s medium policy case includes annual average energy savings of 1,762 GWh per year from 2011 - 2015, with $30 million in associated administrative and marketing costs.

Key elements underlying the estimate of the total rate effect for each efficiency case are as follows:

→ Assumed the Company undertakes direct investments in energy efficiency to offset the estimated annual output of the plant;[29]

→ Assumed these investments occur as *constant annual outlays* rather than a lump-sum initial outlay that declines in rate base over time; and,

→ Assumed, as in the Plant analysis in *Section 3.1*, that the reductions in electricity consumption achieved by the Energy Efficiency Alternative, displace purchased power from the PJM control area. As we described in that section, to properly assess the net cost of energy efficiency to Virginia ratepayers, it is necessary to account for the cost of purchased power that would be displaced by the Plant or, in this case, by undertaking the Energy Efficiency Alternative. As in that analysis, we again included the potential cost of a likely carbon emissions regulation on DVP's purchased power suppliers. The methods used to estimate the avoided cost of purchased power displaced by energy efficiency and the potential additional avoided cost of a carbon emissions management are exactly the same as those described in *Section 3.1*.

This analysis yields total annual costs of the Energy Efficiency Alternative to Virginia ratepayers of approximately $54 million and $118 million for the *low* and *medium* efficiency cost cases, respectively – without accounting for the avoided cost of purchased power otherwise purchased to meet DVP load or the potential cost of a likely carbon emissions regulation on DVP's purchased power providers. *Table 4-3* reports the total *net* rate effect for each case, accounting for the avoided cost of displaced purchased power and a potential carbon management program and subject to the assumptions outlined above.

Table 4-3: Estimated Total Rate Effect of Energy Efficiency Alternative to Virginia Ratepayers

	Impact Analysis Year								
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	No Carbon Emissions Regulation			**Carbon Emissions Program – Low Permit Cost**			**Carbon Emissions Program – Mid Permit Cost**		
***Low Cost Energy Efficiency Case* – Total Rate Impact to Virginia Ratepayers ($ million)**									
Total before Purchased Power Cost Offset	$111	$128	$151	$111	$128	$151	$111	$128	$151
Purchased Power Cost Offset	$269	$310	$361	$290	$345	$423	$320	$395	$514
Net Rate Impact	-$158	-$182	-$210	-$179	-$216	-$272	-$209	-$267	-$363
***Mid Cost Energy Efficiency Case* – Total Rate Impact to Virginia Ratepayers ($ million)**									
Total before Purchased Power Cost Offset	$176	$202	$239	$176	$202	$239	$176	$202	$239
Purchased Power Cost Offset	$269	$310	$361	$290	$345	$423	$320	$395	$514
Net Rate Impact	-$93	-$108	-$123	-$114	-$142	-$184	-$145	-$193	-$276
Source: Abt Associates analysis									

4.3 Allocating the Cost of the Energy Efficiency Alternative to Virginia Ratepayers

As before, we allocated the total rate effect for Virginia ratepayers between residential and non-residential ("business") consumers, and within the business consumers, over the affected economic sectors.

The rate effect was allocated between residential and non-residential ("business") consumers on the basis of energy consumption following the same process for the analysis of the Plant described above in *Section 3.2*. *Table 4-4*, below, summarizes this distribution of the total rate effect for the impact cases outlined in *Table 4-3*, above.

29 At the reported 90 percent capacity utilization rate for the plant (source: DVP Martin testimony) and the assumed assignment of 77.8 percent of the total cost of energy efficiency savings to Virginia customers.

Table 4-4: Allocation of Total Energy Efficiency Rate Effect to Broad Customer Categories									
	Impact Analysis Year								
($ million)	2012	2018	2025	2012	2018	2025	2012	2018	2025
	No Carbon Emissions Regulation			Carbon Emissions Program – *Low Permit Cost*			Carbon Emissions Program – *Mid Permit Cost*		
***Low Cost Energy Efficiency Case* – Distribution of Rate Impact to Virginia Ratepayers ($ million)**									
Total Rate Impact, net of purchased power offset (from *Table 4-3*, above)	-$158	-$182	-$210	-$179	-$216	-$272	-$209	-$267	-$363
Residential	-$71	-$82	-$95	-$81	-$98	-$123	-$94	-$121	-$164
Business	-$85	-$98	-$113	-$96	-$116	-$146	-$112	-$143	-$195
Non-Residential Other	-$2	-$2	-$3	-$2	-$3	-$3	-$3	-$3	-$5
***Mid Cost Energy Efficiency Case* – Distribution of Rate Impact to Virginia Ratepayers ($ million)**									
Total Rate Impact, net of purchased power offset (from *Table 4-3*, above)	-$93	-$108	-$123	-$114	-$142	-$184	-$145	-$193	-$276
Residential	-$42	-$49	-$55	-$51	-$64	-$83	-$65	-$87	-$124
Business	-$50	-$58	-$66	-$61	-$76	-$99	-$77	-$103	-$148
Non-Residential Other	-$1	-$1	-$2	-$1	-$2	-$2	-$2	-$2	-$3
Source: Abt Associates analysis									

In all of the analysis cases and impact years, the total rate effect of the Energy Efficiency Alternative is *negative* – that is, we estimate that the total burden to Virginia ratepayers will decline under the Energy Efficiency Alternative. The decline results from the combination of (1) the lower cost of electricity demand reductions (compared to the Plant's cost of power generation), and (2) the avoidance of any carbon emissions regulation add-on for the electricity demand reduction achieved by the Energy Efficiency Alternative. When the *avoided cost of power purchases*, which occurs in both the Energy Efficiency Alternative and the Plant impact analysis, is subtracted from the cost of the Energy Efficiency Alternative, the result is negative: that is, *ratepayer burden declines*.

4.4 Estimating the Economic Impact of Rate Changes to Residential Customers under the Energy Efficiency Alternative

We estimated the economic impact of rate changes from energy efficiency investments to residential customers, and in turn, the broader Virginia economy using the same methodology described in Section 3.3.

This approach includes two principal steps:

1. Allocating the total residential custome

2. Estimati
for Virginia.

The results of this analysis, reported in *Table 4-5*, show a significant net increase in economic activity in Virginia due to the net reduction in residential rates from the Energy Efficiency Alternative.

Table 4-5: Total Economic Impact in Virginia Due to Residential Rate Changes under the Energy Efficiency Alternative									
	Impact Analysis Year								
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	No Carbon Emissions Regulation			**Carbon Emissions Regulation – Low Permit Cost**			**Carbon Emissions Regulation – Mid Permit Cost**		
Low Cost Energy Efficiency Case									
GSP	$115	$132	$153	$130	$157	$197	$152	$194	$264
Employment (jobs)	978	1,128	1,302	1,106	1,340	1,685	1,296	1,654	2,250
Earnings	$38	$43	$50	$43	$52	$65	$50	$64	$87
Mid Cost Energy Efficiency Case									
GSP	$68	$78	$89	$83	$103	$134	$105	$140	$200
Employment (jobs)	578	667	759	706	880	1,142	896	1,194	1,707
Earnings	$22	$26	$29	$27	$34	$44	$35	$46	$66
Source: Abt Associates analysis									

4.5 Estimating the Economic Impact of Rate Changes to Business Customers under the Energy Efficiency Alternative

We estimated the economic impact of rate changes from energy efficiency investments to DVP's business customers, and in turn, the broader Virginia economy using the same methodology described in Section 3.4.

This approach includes three principal steps:

1. Allocating the total business customer effect over a
2. Estimating the change in economic activity in primary i
3. Estimating the total economic impa

Like the analysis for residential customer rate effects, reported above, the business customer rate effect analysis, reported in *Table 4-6*, shows a significant net increase in economic activity in Virginia due to the net reduction in business sector rates from the Energy Efficiency Alternative.

Table 4-6: Total Economic Impact in Virginia Due to Business Sector Rate Changes under the Energy Efficiency Alternative									
	Impact Analysis Year								
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	No Carbon Emissions Regulation			**Carbon Emissions Regulation – Low Permit Cost**			**Carbon Emissions Regulation – Mid Permit Cost**		
Low Cost Energy Efficiency Case									
GSP	$73	$84	$96	$83	$100	$124	$97	$123	$165
Employment (jobs)	495	573	664	560	681	860	656	841	1,148
Earnings	$23	$26	$30	$26	$31	$39	$30	$38	$52
Mid Cost Energy Efficiency Case									
GSP	$43	$50	$56	$53	$65	$84	$67	$89	$125
Employment (jobs)	292	339	387	357	447	583	453	607	871
Earnings	$13	$16	$18	$16	$20	$27	$21	$28	$40
Source: Abt Associates analysis									

4.6 Combining the Residential and Business Customer Rate Effects under the Energy Efficiency Alternative

Table 4-7 reports our estimate of the total economic impact to Virginia of the rate changes to residential and business customers from the Energy Efficiency Alternative.

Table 4-7: Total Economic Impact in Virginia Due to Residential Rate Changes under the Energy Efficiency Alternative

	Impact Analysis Year								
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	No Carbon Emissions Regulation			**Carbon Emissions Regulation – Low Permit Cost**			**Carbon Emissions Regulation – Mid Permit Cost**		
Low Cost Energy Efficiency Case									
GSP	$188	$216	$249	$213	$257	$321	$249	$317	$429
Employment (jobs)	1,473	1,701	1,966	1,666	2,021	2,545	1,952	2,495	3,398
Earnings	$61	$69	$80	$69	$83	$104	$80	$102	$139
Mid Cost Energy Efficiency Case									
GSP	$111	$128	$145	$136	$168	$218	$172	$229	$325
Employment (jobs)	870	1,006	1,146	1,063	1,327	1,725	1,349	1,801	2,578
Earnings	$35	$42	$47	$43	$54	$71	$56	$74	$106

Source: Abt Associates analysis

As shown in *Table 4-7*, we estimate that the impact on the Virginia economy of the rate changes due to the Energy Efficiency Alternative will be substantial and, unlike the economic impact of the rate effect from the Plant, *uniformly beneficial*. As described above, the combination of (1) the lower unit cost of demand reductions compared with the cost of electricity supplied by the Plant, (2) the avoidance of any carbon emissions management program impact on the electricity consumption displaced by the Energy Efficiency Alternative and (3) deduction of the continuing avoided cost of purchase power, yield an overall *negative* cost from the Energy Efficiency Alternative. As a result, the economic impact on Virginia of the Energy Efficiency Alternative's rate effect is positive.

Under the *Mid Permit Cost* carbon emissions regulation case, the impact in terms of gain in economic output ranges from $172 - $249 million in 2012, increases to $229 - $317 million in 2018, and increases again to $325 - $429 million in 2025. The impacts are smaller under the *Low Permit Cost* case, but still substantial with output gains of $136 - $213 million in 2012, $168 - $257 million in 2018, and $218 - $321 million in 2025. As we described previously, we view the carbon emissions regulation cases as providing the more realistic assessment of expected economic outcomes.

These output impacts are accompanied by gains in jobs and employee earnings. Under the *Mid Permit Cost* carbon emissions program case, the employment gain averages 1,909 - 2,615 jobs over the three analysis years, depending on the Energy Efficiency Alternative case, and the employee income gain averages $107 - $321 million over the three years.

4.7 Assessing the Economic Impact of the Outlays for the Energy Efficiency Alternative

Sections 4.2 - 4.6 presented the analysis of economic effects due to estimated changes in electricity rates under the Energy Efficiency Alternative. This section assesses the economic effect of the outlays for energy efficiency – that is, the increases in economic output and employment in Virginia that result from the investments and ongoing operating and maintenance of the energy efficiency investments.

These effects are analogous to the increases in output and employment that would result from the construction and operation of the Plant. The Energy Efficiency Alternative outlays were reported above, in *Table 4-3*, and are summarized again in *Table 4-8*, below. The estimates of total outlay are based on the presumption that the utility makes sufficient investments in energy efficiency to offset what would otherwise be the annual output of the Plant, as described previously in *Section 4.2*.

Table 4-8: Annual Outlays for the Energy Efficiency Alternative						
	Impact Analysis Year					
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	Low Cost Energy Efficiency Case			**Mid Cost Energy Efficiency Case**		
Total Annual Outlay	$143	$165	$194	$226	$260	$307
Source: Abt Associates analysis						

To estimate the economic effect of these outlays in the broader Virginia economy, we allocated the outlays to sectors of the Virginia economy that, based on our professional judgment, would likely engage in the manufacture, installation, and service of energy efficiency services (manufacturing, electrical equipment, and miscellaneous services). Given the size and diversity of the Virginia economy, we further assumed that a substantial share of these outlays – 75 percent – would be for *purchase of goods, services, and labor in Virginia* (i.e., the *local* content of the energy efficiency outlay). Without a better defined policy concept regarding the specific energy efficiency investments to be undertaken and where within the DVP service territory these investments would occur (i.e., in Virginia or North Carolina), we cannot know to what extent this assumption over- or under-states the fraction of the outlays that would flow as a first-order effect to the Virginia economy.

We then used the input-output multiplier framework to estimate the effect of spending in these sectors on linked sectors in the local economy. *Table 4-9*, below, presents the estimated total economic impact of these outlays, in terms of increased GSP, employment, and labor earnings.

Table 4-9: Economic Impact of Outlays for the Energy Efficiency Alternative						
	Impact Analysis Year					
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	Low Cost Energy Efficiency Case			**Mid Cost Energy Efficiency Case**		
GSP	$166	$192	$226	$263	$303	$357
Employment	1,152	1,327	1,564	1,822	2,097	2,472
Earnings	$51	$58	$69	$80	$92	$108
Source: Abt Associates analysis						

As reported in *Table 4-9*, we estimate that the outlays for the Energy Efficiency Alternative will have a substantial beneficial effect on the overall Virginia economy under both the low- and mid cost energy efficiency cases. Under the Low Cost Case, the total output increase averages $195 million over the three analysis years; under the Mid Cost Case, the total output increase averages $308 million over the three years.

4.8 Assessing the Aggregate Economic Impact from Changes in Electricity Rates and Energy Efficiency Outlays under the Energy Efficiency Alternative

The Energy Efficiency Alternative produces economic effects in Virginia through two primary mechanisms:

1. Econom
   associated with these energy efficiency outlays; and

2. Econom

The economic effects of the first mechanism were analyzed previously in *Sections 4.2 - 4.6* and the effects of the second mechanism were analyzed in *Section 4.7*. This section estimates the net effects of both economic impact mechanisms (i.e., aggregate results of *Table 4-8* and *Table 4-9*).

Table 4-10, following page, reports our estimated aggregate net economic impacts of the Energy Efficiency Alternative cases, accounting for both (1) the economic effects of the energy efficiency outlays and (2) the associated changes in electricity rates.

Table 4-10: Aggregate Annual Net Economic Impacts in Virginia from the Energy Efficiency Alternative									
	Impact Analysis Year								
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	No Carbon Emissions Regulation			**Carbon Emissions Regulation – *Low Permit Cost***			**Carbon Emissions Regulation – *Mid Permit Cost***		
Low Cost Energy Efficiency Case									
GSP	$355	$407	$474	$379	$448	$546	$415	$508	$655
Employment (jobs)	2,625	3,028	3,530	2,818	3,348	4,108	3,104	3,821	4,962
Earnings	$111	$127	$149	$119	$141	$173	$131	$161	$208
Mid Cost Energy Efficiency Case									
GSP	$374	$430	$502	$399	$471	$575	$435	$531	$682
Employment (jobs)	2,692	3,103	3,618	2,885	3,424	4,196	3,171	3,898	5,050
Earnings	$115	$133	$155	$123	$146	$179	$136	$166	$214
Source: Abt Associates analysis									

As shown in *Table 4-10*, we estimate that the aggregate effect of the Energy Efficiency Alternative on the Virginia economy will be positive and substantial for all analysis cases and impact years. The beneficial economic effects increase over time for each of the analysis cases, and increase as well under the Carbon Emissions Regulation cases compared to the No Carbon Emissions Regulation case. The beneficial effects also increase in the Mid Cost Efficiency Case compared to the Low Cost Case because of the greater increases in output and employment that result from the energy efficiency investments under the Mid Cost Efficiency Case.

5. Comparing the Power Plant and the Energy Efficiency Alternative

Chapter Summary

In the preceding chapters, we assessed the impact on the Virginia economy of the Virginia City Plant and the alternative approach of investing in energy efficiency to meet Virginia's electricity needs. In this chapter, we bring the findings together from these separate assessments.

Overall, our analysis finds that the Energy Efficiency Alternative appears to offer a significantly superior economic alternative to meeting Virginia's electricity needs. We found the Energy Efficiency Alternative to be substantially less costly for ratepayers, and also substantially more beneficial for the economy in all cases, and particularly when a likely carbon emissions regulation is taken into account. We view the carbon emissions regulation cases as providing the more realistic assessment of expected economic outcomes.

Under the *mid carbon Permit Cost case* and *mid energy efficiency cost case*, the relative net impact of the Energy Efficiency Alternative in terms of economic output is $483 million in 2012, and increases considerably to $675 million by 2025. The output gains are accompanied by gains in jobs and employee earnings. For example, under the *mid carbon Permit Cost case* and *mid energy efficiency cost case*, the net employment gain from energy efficiency is 4,117 in 2012 and increases to 6,051 by 2025.

As described in the preceding sections, we found that the Virginia City Plant is likely to cause a *relatively small* net gain to the Virginia economy (i.e., the negative economic impacts of the rate effects are outweighed by the positive impacts associated with Plant operations) *in the absence of a carbon emissions regulatory program*. However, with a future carbon emissions regulatory program – which we judge as highly likely – the net positive effects of the Plant are substantially diminished. For example, the Plant yields a loss of jobs in the Virginia economy under the *mid Permit Cost* carbon regulation for all analysis years (see *Table 3-13*).

In contrast, as summarized in *Table 4-10*, we find that the Energy Efficiency Alternative would not only be substantially less costly for ratepayers, but would also produce a significantly greater beneficial impact on the economy in all cases, and particularly when a likely carbon emissions regulation is taken into account. Overall, the Energy Efficiency Alternative appears to offer a superior economic alternative to meeting Virginia's electricity needs.

Table 5-1 below compares our findings from these analyses. Each value represents the *gain in output, employment, and employee earnings* estimated to result from the Energy Efficiency Alternative compared to the Plant.

Table 5-1: Comparison of Economic Impacts from the Plant and the Energy Efficiency Alternative

	Impact Analysis Year								
($ million)	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**	**2012**	**2018**	**2025**
	No Carbon Emissions Regulation			**Carbon Emissions Regulation – *Low Permit Cost***			**Carbon Emissions Regulation – *Mid Permit Cost***		
Impact of the Low-Cost Energy Efficiency Case Compared to the Power Plant									
GSP	$323	$276	$228	$380	$370	$397	$464	$510	$647
Employment (jobs)	2,940	2,764	2,639	3,387	3,507	3,980	4,051	4,607	5,963
Earnings	$109	$94	$79	$127	$124	$135	$154	$169	$216
Impact of the Mid-Cost Energy Efficiency Case Compared to the Power Plant									
Economic Output	$342	$299	$255	$399	$393	$425	$483	$533	$675
Employment (jobs)	3,006	2,839	2,727	3,454	3,584	4,068	4,117	4,683	6,051
Earnings	$113	$100	$85	$131	$129	$141	$159	$174	$223
Source: Abt Associates analysis									

Table 5-1 shows that, when compared to the Plant, an approach that procures an equivalent amount of electricity via energy efficiency-based demand reduction has significant positive net impacts on the Virginia economy. In other words, the potential Energy Efficiency Alternatives are more beneficial to the Virginia economy than the Plant.

Under the *mid permit cost* carbon emissions regulation case, the relative net impact of the Energy Efficiency Alternatives in terms of economic output ranges from $464 to $483 million in 2012, and increases considerably to a range of $647 to $675 million by 2025. As we described previously, we view the carbon emissions regulation cases as providing the more realistic assessment of expected economic outcomes.

These output impacts are accompanied by similarly relative impacts on jobs and employee earnings in Virginia. Under the *mid permit cost* carbon emissions program case, the net employment gains from energy efficiency average 4,874 to 4,950 jobs over the three analysis years, depending on the efficiency case. Net gains in employee income average $180 to $185 million over the three years.

As we discussed in *Chapter 4: Assessing the Energy Efficiency Alternative*, we recognize that institutional barriers exist to pursuing the Energy Efficiency Alternative. For instance, under typical regulatory structures, utilities often do not have an economic incentive to offer energy efficiency or other demand-side programs because reduced electricity sales reduce utility revenues and earnings (Kushler et al. 2006). In addition, we recognize that the Energy Efficiency Alternatives outlined in this report represent illustrative cases based on cost-effective energy efficiency *potential*, rather than based on a specific set of energy efficiency measures or a program to implement those energy efficiency measures. Nevertheless, these analyses – and numerous real-world examples – demonstrate that energy efficiency can contribute a relative economic gain compared with traditional supply-side approaches for meeting growing electricity demand and ought to be considered a priority energy resource as part of any IRP process.

6. Assessing the Health Effects of the Plant's Air Pollutant Emissions

In addition to assessing the effects on GSP and employment from the Plant and the Energy Efficiency Alternative as outlined in the preceding sections, we also analyzed the effect of the Plant's air pollution emissions on human health and related economic effects in Virginia. The Plant will be required to meet strict New Source Performance Standards (NSPS) for applicable pollutant emissions. However, because the Plant will burn a very large quantity of coal, it will still emit substantial air pollutants and these *allowed* emissions will adversely affect regional air quality and human health. The Energy Efficiency Alternative has no such air pollution effects.

As reported in air permits issued by the Virginia Department of Environmental Quality (DEQ) on June 30, 2008, the Plant is subject to the aggregate annual pollutant emission limits summarized in *Table 6-1*.[30]

Table 6-1: Emissions Limits for the Virginia City Plant

Pollutant	Emissions Limit (tons/year)
Filterable Particulate Matter (PM)	246.9
Total PM-10 (filterable and condensable)	329.2
Total PM-2.5 (filterable and condensable)	329.2
Sulfur Dioxide	603.6
Nitrogen Oxides (as NO_2)	1,920.5
Carbon Monoxide	4,115.5
Volatile Organic Compounds (VOCs)	137.2
Sulfuric Acid Mist (H_2SO_4)	96.0
Hydrogen Fluoride	12.9
Hydrogen Chloride	181.1

Source: Commonwealth of Virginia DEQ, registration number 11526

In particular, this analysis focuses on the effect of increased ambient concentrations of particulate matter less than 2.5 microns in aerodynamic diameter ($PM_{2.5}$ or fine particulate matter), which is a harmful air pollutant linked with several serious health effects, including hospitalization for respiratory and cardiovascular illnesses, chronic bronchitis, and premature mortality. $PM_{2.5}$-related health effects results framework the Plant's emissions of $PM_{2.5}$, as well as sulfur dioxide (SO_2), oxides of nitrogen (NO_x) and volatile organic compounds (VOCs), all of which contribute to the formation of $PM_{2.5}$.

To estimate the $PM_{2.5}$-related health impacts associated with the Plant's emissions, we used the Co-benefits Risk Assessment (COBRA) Model, a peer-reviewed model developed by Abt Associates for the U.S. Environmental Protection Agency (EPA). Given the Plant's estimated emissions, COBRA first calculates the number of adverse health impacts (e.g., additional deaths) and then estimates the associated economic effects. This process is the standard approach for evaluating the health and economic benefits of reduced air pollution. EPA has previously used this approach when evaluating National Ambient Air Quality Standards (U.S. EPA 2006b), the Clean Air Act (U.S. EPA 1999), the benefits of reducing greenhouse gases (Abt Associates 1999), the health effects of motor vehicles (U.S. EPA 2000, 2004), and other major regulations.

30 DVP has obtained permits to construct and operate a coal-fired steam electric generating plant in accordance with the provisions of 9 VAC 5-80 Articles 6, 7, and 8 of the Virginia State Air Pollution Control Board Regulations for the Control and Abatement of Air Pollution (the permits can be downloaded here: http://www.deq.virginia.gov/info/vchecPermits.html).

The remainder of this Chapter reports the results from the COBRA analysis in 2015 and 2020 (*Section 6.1*), reviews the COBRA model (*Section 6.2*), summarizes the health end-points included in the analysis of Plant emissions (*Section 6.3*), and summarizes COBRA's health impact monetization concepts (*Section 6.4*).

6.1 Estimated Health Effects of the Plant's Air Pollutant Emissions

The effects of the Plant's emissions will be felt in Virginia and in areas outside of Virginia as these air emissions disperse in the atmosphere. Below, we report the estimated number of additional $PM_{2.5}$ related health effect cases, and the associated economic effect, from the Plant's emissions of $PM_{2.5}$, SO_2, NO_x, and VOCs. *Table 6-2* reports the results for residents in Virginia, and *Table 6-3* reports the national level results. Most of the additional impact reported in the national level results occurs in other near-by states.

The results of the COBRA analysis indicate that, although the Plant will be required to meet stringent New Source Performance Standards (NSPS) for applicable pollutant emissions and will be subject to all applicable air emission limits under federal and state air pollution programs, the *allowed* emissions from the Plant will affect regional air quality and human health. In Virginia, increased pollutant emissions are estimated to contribute to 2 - 5 additional premature mortality events on an annual basis. Nationally, the increased emissions are estimated to contribute to between 5 and 14 additional premature mortality events annually. In addition, these emissions will contribute to a significant increased occurrence of non-fatal health impacts both in Virginia and in areas outside Virginia.

The total annual economic value of these health impacts ranges from about $16 to $52 million for Virginia, and $44 to $135 million for the entire United States.

Table 6-2: Health Impacts of Increased $PM_{2.5}$, NO_x, SO_2, and VOC Emissions in Virginia

Health End-Point	**Impact in Virginia**			
	Additional Cases		*Economic Impact (thousands)*	
	2015	*2020*	*2015*	*2020*
Premature Mortality	1.9 - 4.8	2.0 - 5.2	$14,823 - $39,529	$19,448 - $50,009
Chronic Bronchitis	1.3	1.4	$729	$917
Non-Fatal Heart Attacks	2.7	3.0	$358	$458
Respiratory Hospital Admissions	0.4	0.5	$8	$10
Cardiovascular Hospital Admissions	1.0	1.1	$35	$44
Asthma Emergency Room Visits	2.1	2.3	$1	$1
Acute Bronchitis	3.2	3.4	$2	$2
Upper Respiratory Symptoms	28	31	$1	$1
Lower Respiratory Symptoms	37	40	$1	$1
Minor Restricted Activity Days	1,500	1,600	$117	$139
Work Loss Days	260	270	$30	$35
Asthma Exacerbations	35	38	$2	$3
Total			**$16,100 - $40,800**	**$21,100 - $51,600**

Source: Abt Associates analysis

Table 6-3: Nationwide Health Impacts of Increased $PM_{2.5}$, NO_x, SO_2, and VOC Emissions				
Health End-Point	**National Impacts**			
	Additional Cases		*Economic Impact (thousands)*	
	2015	*2020*	*2015*	*2020*
Premature Mortality	5 - 13	5 - 14	$40,764 - $104,998	$51,398 - $130,578
Chronic Bronchitis	3.1	3.3	$1,853	$2,223
Non-Fatal Heart Attacks	7.9	8.7	$1,062	$1,320
Respiratory Hospital Admissions	1.2	1.3	$21	$26
Cardiovascular Hospital Admissions	2.7	3.0	$93	$115
Asthma Emergency Room Visits	4.6	4.9	$2	$3
Acute Bronchitis	7.6	8.1	$4	$5
Upper Respiratory Symptoms	68	73	$2	$3
Lower Respiratory Symptoms	90	96	$2	$3
Minor Restricted Activity Days	3,700	3,800	$284	$333
Work Loss Days	630	650	$73	$85
Asthma Exacerbations	84	90	$5	$7
Total			**$44,200 - $108,400**	**$55,500 - $134,700**
Source: Abt Associates analysis				

6.2 Overview of COBRA

Abt Associates developed the Co-Benefits Risk Assessment Tool (COBRA) for EPA to support assessments of the human health effects of air pollution reductions and their associated economic effects. COBRA results from years of research and development, and reflects methods that are based on the peer-reviewed health impacts analysis literature. COBRA itself underwent a peer review in 2005, and a revised version was developed that addressed many of the peer review comments. We used this revised version of COBRA for the present analysis.[31]

In general, COBRA is based on a *damage function* approach, which involves modeling changes in ambient air pollution levels, calculating the associated change in adverse health effects, such as premature mortality, and then assigning an economic value to these effects. For changes in the concentrations of particulate matter and ozone, this is typically done by translating a change in pollutant levels into associated changes in human health effects. These health effects are then translated into economic values.

A COBRA analysis relies on first obtaining an estimate of the change in air pollution emissions. This calculation occurs outside of COBRA and is used as input to the COBRA analysis. For this analysis, the increase in pollutant emissions is assumed to be equal to the Plant's emission limits specified in *Table 6-1*. After entering this information into COBRA, the model then performs three broad steps:

1. **Estimate the reduction in ambient $PM_{2.5}$ levels in each county in Virginia and the surrounding region.** To estimate reductions in ambient $PM_{2.5}$ levels, COBRA uses a Source-Receptor (S-R) Matrix air quality model, which is embedded in the COBRA model. The S-R matrix translates air pollution emissions changes into changes in ambient concentrations for each county in the continental United States. The COBRA S-R matrix has two basic building blocks:[32]
    - An *emissions inventory*, which includes the following pollutants that are relevant to $PM_{2.5}$ formation: sulfur dioxide (SO_2), NO_x, direct emissions of $PM_{2.5}$, ammonia (NH_3), and VOCs. The matrix has emissions data for several thousand identifiable point sources in the United States, Canada and Mexico – *including the specific Plant that is the focus of this analysis*. The inventory also includes more diffuse "area" emissions, such as from motor vehicles and small point sources.

31 More information on COBRA can be found at http://www.epa.gov/cleanenergy/energy-programs/state-and-local/by-topic/economics.html.

32 Refer to Appendix A of the COBRA manual for additional details on COBRA's S-R matrix and emissions inventory.

- *Transfer coefficients*. The S-R matrix has a transfer coefficient from each source of emissions (point or area) to each county in the continental United States for four pollutants: (1) directly emitted, or primary particulate matter, and organics; (2) SO_2; (3) NO_x; and, (4) NH_3.

2. **Estimate the change in the incidence of adverse health effects**. This step in the process involves *health impact functions*, which are derived from concentration-response functions reported in the peer-reviewed epidemiological literature. Health impact functions come in many forms, but a typical health impact function has four components:[33]

   - An *effect estimate*, which quantifies the change in health effects per unit of change in a pollutant, and is derived from a particular concentration-response function from an epidemiology study;
   - A *baseline incidence rate* for the health effect;
   - The *affected population*; and,
   - The estimated *change in the concentration* of the pollutant.

   The result of these functions is an estimated change in the incidence of a particular health effect for a given change in air pollution levels. Examples of health effects that have been associated with changes in air pollution levels include premature mortality, hospital admissions for respiratory and cardiovascular illnesses, and asthma exacerbation.

3. **Estimate the economic value of changes in adverse health effects**. This step utilizes *unit values* that give the estimated economic value of avoiding a single case of a particular health endpoint – a single death, for example, or a single hospital admission. These unit values are derived from the economics literature, and come in several varieties:[34]

   - For some endpoints, such as hospital admissions, COBRA uses *cost of illness* (COI) unit values, which estimate the cost of treating or mitigating the effect. COI unit values generally underestimate the true value of reductions in risk of a health effect since they include hospital costs and lost wages, but do not include any estimate of the value of avoided pain and suffering.
   - For other endpoints, such as asthma exacerbation, we use *willingness to pay* (WTP) unit values, which are estimates of willingness to pay to avoid an asthma exacerbation.
   - Typically, *value of statistical life* (VSL) unit values are used for reductions in risk of premature mortality.

   The calculation of total health-related economic effects involves summing estimated effects across all non-overlapping health effects, such as hospital admissions for pneumonia, chronic lung disease, and cardiovascular-related problems.

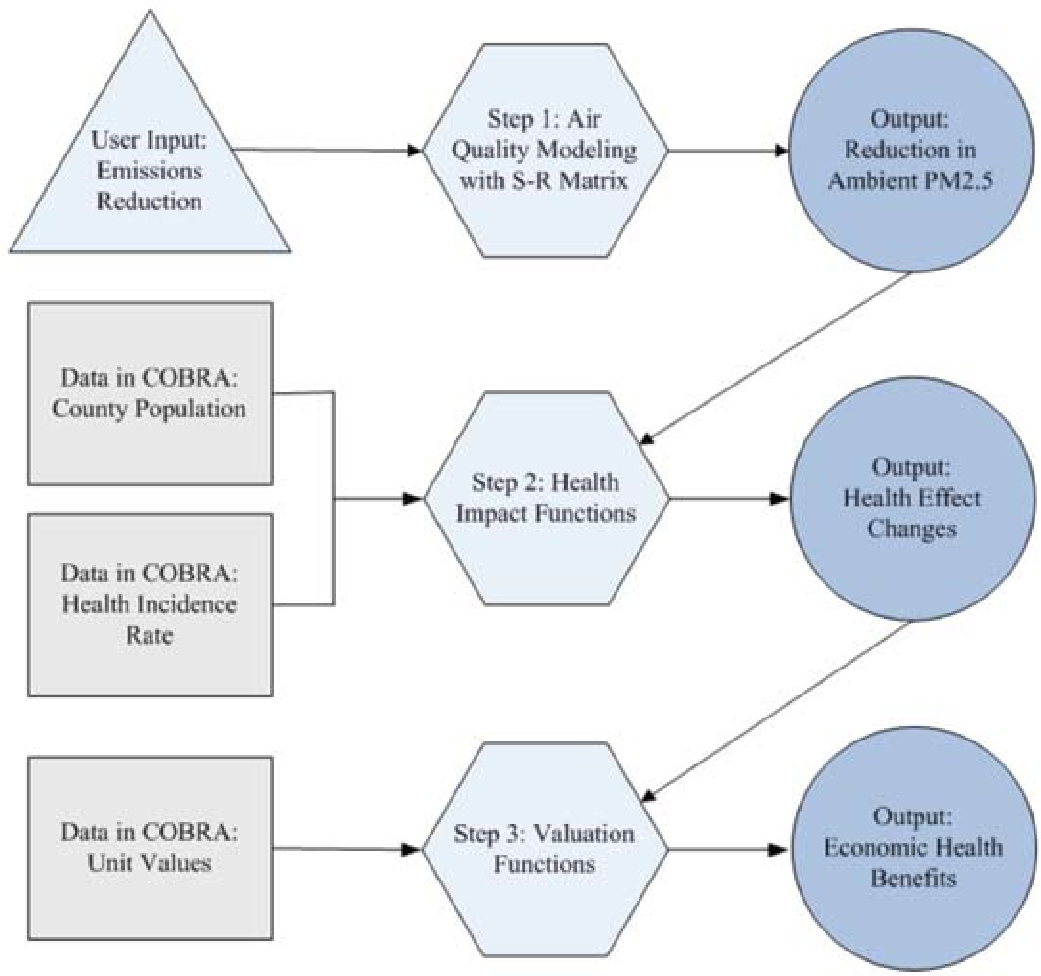
It is important to note that the Plant's pollutant emissions can affect ambient concentrations of air pollutants other than $PM_{2.5}$, such as ozone, CO, and nitrogen dioxide (NO_2). A careful examination of all of these other pollutants is beyond the scope of this analysis. As a result, our analysis will tend to underestimate the likely health effects of the Plant's emissions. In addition, as with more complex air pollution impact models, there is uncertainty surrounding the values of key inputs to COBRA – in the air quality model, emissions inventory, health impact functions, and economic values – and caution should be exercised when interpreting the results of analyses. Some of the uncertainty in COBRA reflects variability (for example, a health impact function that is appropriate for one location may not be appropriate for another location if the function actually varies across locations). Much of the uncertainty, however, reflects the insufficient level of knowledge about the true values of model inputs.

Figure 6-1, following page, illustrates the flow of data through the COBRA model.

33 Refer to Appendices C, D, and E of the COBRA manual for additional details on the specific form of the health impact functions, and descriptions of the health incidence rates and population data used in these functions.

34 Refer to Appendix F of the COBRA manual for additional details on the economic value assigned to health effects.

Figure 6-1: COBRA Model Data Flow



6.3 Summary of Included Health End-Points

This section summarizes the individual health effects associated with $PM_{2.5}$ exposure and the functions used to quantify the number of cases of various health effects that are expected to result from the Plant's pollutant emissions. As noted previously, refer to Appendices C and D of the COBRA manual for additional details on all of the epidemiological studies and the specific forms of the health impact functions used to model these end-points in COBRA.

Premature Mortality

Health researchers have consistently linked air pollution, especially PM, with excess mortality. Although a number of uncertainties remain to be addressed, a substantial body of published scientific literature recognizes a correlation between elevated PM concentrations and increased mortality rates. Both long- and short-term exposures to ambient levels of particulate matter air pollution have been associated with increased risk of premature mortality. It is clearly an important health endpoint because of the size of the mortality risk estimates, the serious nature of the effect itself, and the high monetary value ascribed to avoiding mortality risk. Particulate matter has been linked with premature mortality in adults as well as infants in multiple studies throughout the world. To estimate premature mortality in adults, COBRA uses an epidemiological analysis of the American Cancer Society cohort by Pope et al. (2002). To estimate premature mortality in infants, COBRA uses a study by Woodruff et al. (1997).

Chronic Bronchitis

Chronic bronchitis is characterized by mucus in the lungs and a persistent wet cough for at least three months a year for several consecutive years, and affects roughly five percent of the U.S. population (American Lung Association, 2002). There are a limited number of studies that have estimated the impact of air pollution on new incidences of chronic bronchitis. Schwartz (1993) and Abbey et al. (1995) provide evidence that long-term PM exposure can give rise to the development of chronic bronchitis in the U.S.

Non-Fatal Myocardial Infarction (Heart Attack)

Non-fatal heart attacks have been linked with short-term exposures to $PM_{2.5}$ in the U.S. (Peters et al., 2001) and other countries (Poloniecki et al., 1997). COBRA uses the C-R function reported in Peters et al. (2001), the only available U.S. study to provide an estimate specifically for $PM_{2.5}$-related heart attacks. Other studies, such as Samet et al. (2000) and Moolgavkar et al. (2000), reported a consistent relationship between all cardiovascular hospital admissions, including for non-fatal heart attacks, and PM. However, they did not focus specifically on heart attacks. Given the lasting impact of a heart attack on longer-term health costs and earnings, it is useful to provide a separate estimate for non-fatal heart attacks based on the single available U.S. C-R function.

Cardiovascular and Respiratory Hospital Admissions

Respiratory and cardiovascular hospital admissions are the two broad categories of hospital admissions that have been related to PM exposure. Although the effects associated with respiratory and cardiovascular hospital admissions are estimated separately in the analysis, the methods used to estimate changes in incidence and to value those changes are the same for both broad categories of hospital admissions. Due to the availability of detailed hospital admission and discharge records, there is an extensive body of literature examining the relationship between hospital admissions and air pollution. To estimate avoided cardiovascular hospital admissions associated with reduced $PM_{2.5}$, COBRA uses studies by Moolgavkar (2000, 2003) and Ito (2003).

Asthma-Related Emergency Room (ER) Visits

To estimate the effects of PM air pollution reductions on asthma-related ER visits, COBRA uses the C-R function based on a study of children 18 and under by Norris et al. (1999). Because children tend to have higher rates of hospitalization for asthma relative to adults, this study likely captures the majority of the impact of $PM_{2.5}$ on asthma ER visits in populations under 65, although there may still be significant impacts in the adult population under 65 but over 18. To avoid double-counting of the effects from increasing both hospital admissions and ER visits, COBRA's estimates of hospital admission costs do not include the costs of admission to the ER.

Acute Bronchitis

Around five percent of U.S. children between ages five and seventeen experience episodes of acute bronchitis annually (Adams and Marano, 1995). Acute bronchitis is characterized by coughing, chest discomfort, slight fever, and extreme tiredness, lasting for a number of days. According to the MedlinePlus medical encyclopedia[35], with the exception of cough, most acute bronchitis symptoms abate within 7 to 10 days. COBRA estimates the incidence of episodes of acute bronchitis in children between the ages of 8 and 12 using a C-R function reported in Dockery et al. (1996).

Upper Respiratory Symptoms (URS)

Using logistic regression, Pope et al. (1991) estimated the impact of PM_{10} on the incidence of a variety of minor symptoms in 55 subjects (34 "school-based" and 21 "patient-based") living in the Utah Valley from December 1989 through March 1990. The children in the Pope et al. study were asked to record respiratory symptoms in a daily diary, and the daily occurrences of upper respiratory symptoms (URS) and lower respiratory symptoms (LRS), as defined below, were related to daily PM_{10} concentrations. Pope et al. describe URS as consisting of one or more of the following symptoms: runny or stuffy nose; wet cough; and burning, aching, or red eyes. Levels of ozone, NO_2, and SO_2 were reported low during this period, and were not included in the analysis. The results from the school-based sample are used here.

Lower Respiratory Symptoms (LRS)

Lower respiratory symptoms include symptoms such as cough, chest pain, phlegm, and wheeze. To estimate the link

35 See http://www.nlm.nih.gov/medlineplus/ency/article/000124.htm.

between $PM_{2.5}$ and LRS, COBRA uses a study by Schwartz and Neas (2000). Schwartz and Neas used logistic regression to link LRS in children with a variety of pollutants, including $PM_{2.5}$, sulfate and H+ (hydrogen ion). Children were selected for the study if they were exposed to indoor sources of air pollution: gas stoves and parental smoking. A total of 1,844 children were enrolled in a year-long study that was conducted in different years (1984 to 1988) in six cities.

Minor Restricted Activity Days (MRADs)

Ostro and Rothschild (1989) estimated the impact of $PM_{2.5}$ on the incidence of minor restricted activity days (MRADs) in a national sample of the adult working population, ages 18 to 65, living in metropolitan areas.

Work-Loss Days (WLDs)

Ostro (1987) estimated the impact of $PM_{2.5}$ on the incidence of work-loss days (WLDs), restricted activity days (RADs), and respiratory-related RADs (RRADs) in a national sample of the adult working population, ages 18 to 65, living in metropolitan areas. The annual national surveys used in this analysis were conducted in 1976-1981. Ostro reported that two-week average $PM_{2.5}$ levels were significantly linked to work-loss and RADs and RRADs; however there was some year-to-year variability in the results.

Asthma Exacerbations

COBRA pools the results of studies by Ostro et al. (2001) and Vedal et al. (1998) to derive an estimate of lower respiratory symptoms in asthmatics. In addition to the lower respiratory estimate, COBRA includes an upper respiratory estimate based on a study by Pope et al. (1991).

6.4 Summary of Economic Value Concepts for Monetizing Health Effects

This section summarizes some issues that arise in valuing incidence of adverse health effects and then provides a summary table of the values that are used in COBRA. The key issues discussed in the section include:

→ The use of ex-ante economic values;

→ Updating the COBRA unit value estimates to account for inflation;

→ The possibility that as income changes, willingness-to-pay (WTP) values would also change; and,

→ The derivation of the present discounted value of future benefits, such as in the case of premature mortality that may occur at some point in the future, relative to a change in emissions.

As noted previously, refer to Appendix F of the COBRA manual for additional details on monetizing the individual health effects and the methods used by COBRA.

Ex-Ante Economic Values

The appropriate economic value for a change in a health effect depends on whether the health effect is viewed *ex ante* (before the effect has occurred) or *ex post* (after the effect has occurred). Increases in ambient concentrations of air pollution generally increase the risk of future adverse health affects by a small amount for a large population. The appropriate economic measure is therefore *ex ante* willingness-to-pay (WTP) for changes in risk. However, epidemiological studies generally provide estimates of the relative risks of a particular health effect due to an increase in air pollution. A convenient way to use this data in a consistent framework is to convert probabilities to units of statistical incidences. This measure is calculated by dividing individual WTP for a risk increase by the related observed change in risk.

For example, suppose the risk of premature mortality increases from 1 in 10,000 to 2 in 10,000 (an increase of 1 in 10,000). If individual WTP for this risk reduction is $100, then the WTP for an avoided statistical premature mortality amounts to $1 million ($100/0.0001 change in risk). Using this approach, the size of the affected population is automatically taken into account by the number of incidences predicted by epidemiological studies applied to the relevant population. The same type of calculation can produce values for statistical incidences of other health endpoints. For some health effects, such as hospital admissions, WTP estimates are generally not available. In these cases, COBRA uses the cost of treating or mitigating the effect.

Updating Values for Inflation

The valuation functions were originally developed based on year 2000 dollars. To allow for the effect of inflation, COBRA has been adjusted to reflect prices in 2006. Because some functions are based on willingness to pay to avoid illness, while others are based on cost of illness and/or lost wages, three different inflation indices are used. These are the All Goods Index, the Medical Cost Index, and the Wage Index, respectively. For this analysis, to be consistent with dollars values reported in previous sections, we subsequently converted the constant 2006 dollar values into expected current dollar values for the years 2015 and 2020 (see Results).

Growth in Unit Values Reflecting Growth in National Income

The unit value estimates in COBRA reflect expected growth in real income over time. This is consistent with economic theory, which argues that WTP for most goods (such as health risk reductions) will increase if real incomes increase. There is substantial empirical evidence that the income elasticity of WTP for health risk reductions is positive, although there is uncertainty about its exact value (and it may vary by health effect). Although one might assume that the income elasticity of WTP is unit elastic (e.g., a 10 percent higher real income level implies a 10 percent higher WTP to reduce health risks), empirical evidence suggests that income elasticity is substantially less than one and thus relatively inelastic. As real income rises, the WTP value also rises but at a slower rate than real income.

The effects of real income changes on WTP estimates can influence the estimated value of health effects in two ways: through real income growth between the year a WTP study was conducted and the year for which benefits are estimated, and through differences in income between study populations and the affected populations at a particular time. Following the analysis in the EPA's Clean Air Interstate Rule (CAIR) regulatory impact assessment, COBRA focuses on the former.

The income adjustment in COBRA follows the approach used by EPA (2005), which adjusted the valuation of human health effects upward to account for projected growth in real U.S. income. Faced with a dearth of estimates of income elasticities derived from time-series studies, EPA applied estimates derived from cross-sectional studies. The available income elasticities suggest that the severity of a health effect is a primary determinant of the strength of the relationship between changes in real income and changes in WTP. As a result, EPA (2005) used different elasticity estimates to adjust the WTP for minor health effects, severe and chronic health effects, and premature mortality.

In addition to elasticity estimates, projections of real gross domestic product (GDP) and populations are needed to adjust health effects to reflect real per capita income growth. For consistency with the emissions and impacts modeling, EPA (2005) used national population estimates for the years 1990 to 1999 based on U.S. Census Bureau estimates. These population estimates are based on an application of a cohort-component model applied to 1990 U.S. Census data projections. For the years between 2000 and 2010, EPA applied growth rates based on the U.S. Census Bureau projections to the U.S. Census estimate of national population in 2000. EPA used projections of real GDP provided in Kleckner and Neumann (1999) for the years 1990 to 2010. Using the method outlined in Kleckner and Neumann (1999) and the population and income data described above, EPA (2005) calculated WTP adjustment factors for each of the elasticity estimates. Monetized unit values for each of the categories (minor health effects, severe and chronic health effects, premature mortality, and visibility) are therefore adjusted by multiplying the unadjusted benefits by the appropriate adjustment factor. *Table 6-4* lists these adjustment factors.

Table 6-4: Elasticity Values and Adjustment Factors Used to Account for National Income Growth

Health Effect Category	Central Elasticity Estimate	Adjustment Factor
Minor Health Effect	0.14	1.034
Severe & Chronic Health Effects	0.45	1.113
Premature Mortality	0.40	1.100

Source: EPA (2005)

Because of a lack of data on the dependence of COI on income, and a lack of data on projected growth in average wages, no adjustments are made to estimates based on the COI approach or to work-loss days and worker productivity estimates. This lack of adjustment would tend to result in an under-prediction of the value of health effects in future years, because it is likely that increases in real U.S. income would also result in increased COI (due, for example, to increases in wages paid to medical workers) and increased cost of work-loss days and lost worker productivity (reflecting the consideration that if worker incomes are higher, the losses resulting from reduced worker production would also be higher).

Discounted Present Value of Avoiding Future Mortality

The delay, or lag, between changes in PM exposures and changes in mortality rates is not precisely known. The current scientific literature on adverse health effects, such as those associated with PM (e.g., smoking-related diseases), and the difference in the effect size estimated in chronic exposure studies versus daily mortality studies, suggests that it is likely that not all cases of premature mortality associated with a given incremental increase in PM exposure would occur in the same year as the exposure increase.

Following recent EPA analyses (U.S. EPA 2006b), COBRA assumes a 20-year lag structure, with 30 percent of premature deaths occurring in the first year, 50 percent occurring evenly over years 2 to 5 after the change in $PM_{2.5}$, and 20 percent occurring evenly over years 6 to 20 after the change in $PM_{2.5}$. It should be noted that the selection of a 20-year lag structure is not directly supported by any PM-specific literature. Rather, it is intended to be a best guess at the appropriate time distribution of increased cases of PM-related mortality. As noted by EPA, the distribution of deaths over the latency period is intended to reflect the contribution of short-term exposures in the first year, cardiopulmonary deaths in the 2- to 5-year period, and long-term lung disease and lung cancer in the 6- to 20-year period. Finally, it is important to keep in mind that changes in the lag assumptions do *not* change the total number of estimated deaths but rather the timing of those deaths.

Specifying the lag is important because people are generally willing to pay more for something now than for the same thing later. This time preference for now rather than later is expressed by discounting health effects that occur later. The exact discount rate that is appropriate (i.e., that represents people's time preference) is a topic of much debate. EPA has typically used a discount rate of three percent, and we use a three percent rate for this analysis in conjunction with the 20-year lag structure described above.

Summary of Valuation Functions Used in this Analysis

Table 6-5, following page, summarizes the unit values that we used to estimate the total economic effect of adverse health impacts.

Table 6-5: Unit Values for Economic Valuation of Health Endpoints		
Health End-Point	**Age Range**	**Unit Value (2006$)**
Mortality	0 - 99	$6,400,000*
Chronic Bronchitis	27 - 99	$440,000
Acute Myocardial Infarction, Nonfatal	0 - 24	$29,000
Acute Myocardial Infarction, Nonfatal	25 - 44	$40,000
Acute Myocardial Infarction, Nonfatal	45 - 54	$45,000
Acute Myocardial Infarction, Nonfatal	55 - 64	$120,000
Acute Myocardial Infarction, Nonfatal	65 - 99	$29,000
Acute Myocardial Infarction, Nonfatal	0 - 24	$140,000
Acute Myocardial Infarction, Nonfatal	25 - 44	$150,000
Acute Myocardial Infarction, Nonfatal	45 - 54	$160,000
Acute Myocardial Infarction, Nonfatal	55 - 64	$230,000
Acute Myocardial Infarction, Nonfatal	65 - 99	$140,000
HA, All Cardiovascular (less AMI)	18 - 64	$29,000
HA, All Cardiovascular (less AMI)	65 - 99	$27,000
HA, Asthma	0 - 64	$10,000
HA, Chronic Lung Disease	65 - 99	$17,000
HA, Chronic Lung Disease	65 - 99	$17,000
HA, Chronic Lung Disease (less Asthma)	65 - 99	$16,000
HA, Congestive Heart Failure	65 - 99	$20,000
HA, Dysrhythmia	65 - 99	$20,000
HA, Ischemic Heart Disease (less AMI)	65 - 99	$33,000
HA, Pneumonia	65 - 99	$23,000
Asthma ER Visits	0 - 17	$400
Asthma ER Visits	0 - 17	$340
Acute Bronchitis	8 - 12	$430
Lower Resp. Symptoms	7 - 14	$19
Upper Resp. Symptoms	9 - 11	$30
Asthma Exacerbation, Cough	6 - 18	$52
MRAD	18 - 64	$61
Work Loss Days	18 - 64	**

Source: Abt Associates analysis
* Mortality value after adjustment for 20-year lag.
** County-specific median daily wage.

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