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National and State Economic and Environmental Impacts of NETL

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Research Paper Series

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Abstract

This report documents the development of state-level input-output models for Pennsylvania and West Virginia and the augmentation of the national input-output model with employment data. The models were developed to assess the economic and environmental impacts of expenditures and employment at, and research and development awards originating from, the National Energy Technology Laboratory (NETL) sites located in Pittsburgh, PA and Morgantown, WV.

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National and State Economic and Environmental Impacts of NETL

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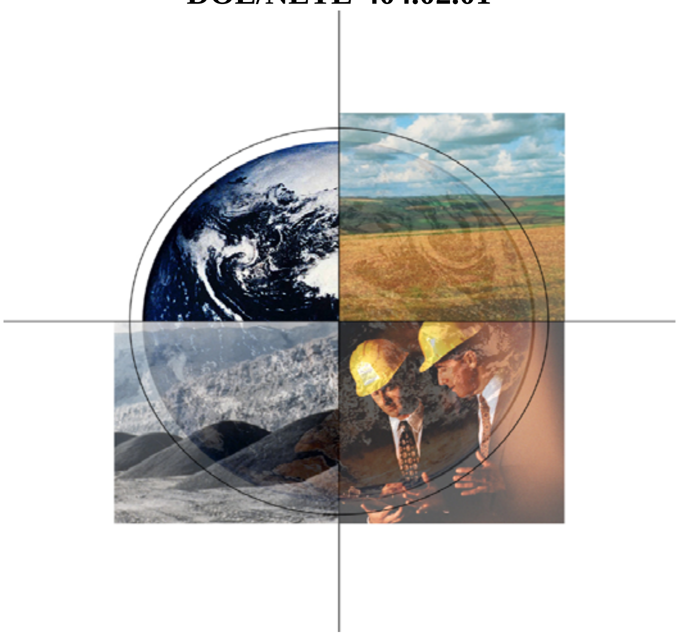

University Partnership Final Report

July 31, 2007

Carnegie Mellon
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West Virginia University

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National and State
Economic and Environmental Impacts of NETL

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University Partnership Final Report
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Executive Summary

As part of the University Partnership program at the National Energy Technology Laboratory (NETL), NETL collaborated with Carnegie Mellon University (CMU) and West Virginia University (WVU) to develop and conduct this project – *National and State Economic and Environmental Impacts of NETL.*

This report documents the development of state-level input-output models for Pennsylvania and West Virginia and the augmentation of the national input-output model with employment data. The models were developed to assess the economic and environmental impacts of expenditures and employment at, and research and development awards originating from, the National Energy Technology Laboratory (NETL) sites located in Pittsburgh, PA and Morgantown, WV.

The primary goal of this project was to develop a fully defensible and transparent means for routinely estimating state and national economic and environmental impacts derived from NETL employment and activity. The development of this methodology and these models allows NETL to assess its influence with respect to the regional economy and to evaluate scenarios that represent alternative activity levels and expenditure allocations.

This project expands NETL's analytical capabilities by producing economic models that allow for the calculation of both direct and indirect impacts and by adding employment data. Further, the work conducted through this collaborative effort lays the groundwork for future analysis to be completed using a consistent methodology.

The models constructed through this effort are available to users via two easily accessible means – a web-based model and MatLab. This accessibility allows target audiences, which include governmental decision makers, industry experts and researchers, to utilize the national and state models for their own environmental and economic impact analysis related to the nation and the states of Pennsylvania and West Virginia.

Constructing new models for an economic and environmental analysis presents four primary challenges which lead to the identification of several key decision points. The four primary challenges were:

1. Identifying quality data sets for economic and environmental parameters;
2. Selecting a methodology for regionalizing the national model;
3. Identifying and collecting NETL data sets;
4. Defining sensible approaches to implementing the model.

The principals guiding the decisions for which data sets to use and which regionalization method to employ were driven by the objective of developing a methodology that is complete, consistent and theoretically sound.

As noted, this project uses input-output (IO) models to derive the economy-wide impacts of NETL's activity. IO models were chosen for this project because they represent the economic relationships between all the sectors of the economy and because the underlying theory of IO models has been well tested and documented. Input-output models are used by economists to trace the direct, indirect requirements from industries that are required for the production and delivery to final demand of specified levels of final demand. The final demand is specified on an industry by industry basis. Under the assumption that the input requirements per dollar of output remain constant for the period of analysis, the backward requirements for inputs from each supplying industry are traced through the supply chain. Input-output analysis was developed by Vassily Leontief in the 1930s and 1940s, and has become thoroughly entrenched in the economics literature. Leontief received a Nobel Prize in economics for his work, as did Richard A. Stone for the development of the social accounting framework, which is essentially an extension of classical input-output economics. During the several decades following Leontief's initial contributions, a voluminous literature has developed focusing on refinements of and extensions to the classical input-output model. Included among these works are the areas of input-output based environmental modeling and methods for estimating regional input-output models by combining national data with region-specific industry-specific data. More detail on assumptions of IO modeling theory is provided in Section V of this report. The IO construct used for these models is CMU's National Environmental Input-Output (EIO) model which allows for the estimation of both economic and environmental impacts of a supply-side change in the economy.

To generate the regional tables for Pennsylvania, West Virginia, and the Combined (Pennsylvania and West Virginia) region, the established location quotient (LQ) method was used in conjunction with the employment vectors described in Section VII. While the LQ is not as complex as some of the alternatives, its properties are well known and understood, its application is straightforward, and its costs are moderate and hence consistent with the scope of this project.

Because IO models assume static, linear relationships between sectors, industries are best compared using IO multipliers. These multipliers are used as convenient summaries for purposes of comparing industrial economic structures across regions or nations. In the EIO-LCA model households are exogenous. Therefore, Type I multipliers, which represent the total (direct and indirect, but excluding induced) output from all industries in the region necessary to satisfy a dollar's worth of final demand for regional industry output are reported.

The data used to represent NETL's 2006 activity at the Pittsburgh, PA and Morgantown, WV sites includes:

*Federal employment: 510 employees
*Federal wages and salaries: $56.4 million
*Federal operational expenditures: $80.8 million
*Federal R&D award obligations: $752.4 million (all NETL sites)
*Federal R&D award costs: $535.0 million (all NETL sites)
*Site Support Contractor employment: 668 employees
*Site Support Contractor wages and salaries: $40.2 million
*Site Support Contractor expenditures: $13.6 million

The data listed above represents the entire value of activities at the Pittsburgh and Morgantown sites regardless and is thus greater than the value of the activities that directly impact Pennsylvania and West Virginia. Details on the portions of the above activities that represent direct impacts on the states of Pennsylvania and West Virginia are provided in Section IX of this report.

RESULTS

Economic activity at NETL was represented in the EIO models using NAICS Sector 541700 – Scientific Research and Development Services. This classification is consistent with reports filed by NETL with Federal agencies and with guidance provided in the NAICS documentation.

The first step in the analysis of NETL impacts was to establish a baseline. Data collected were categorized by the state on which the economic activity had an impact. For example, if the Pittsburgh, PA site expended $45 million on operations and $7 million of that was paid to vendors within the state of Pennsylvania, then $7 million was used as part of the total in determining the impact of NETL's Pittsburgh site on the state of Pennsylvania. Similarly, when determining the impact of NETL's Pittsburgh and Morgantown, WV sites on the PA/WV region, the value of expenditures paid to vendors in both states was used as the value of the combined sites' impact.

Baseline impacts were established for the impact of the Pittsburgh and Morgantown sites on four regions: Pennsylvania, West Virginia, the combined Pennsylvania and West Virginia region, and the nation. Abbreviated results are shown in Table 1 and detailed results are presented in Section X.

Table 1. Baseline Scenarios

	Pennsylvania	West Virginia	Combined States of PA and WV	Nation
Federal, Contractor and R&D Awards/Grants (2006$)	$117.5 million	$74.8 million	$192.4 million	$726 million
Federal and Contractor Employment (2006 jobs)	629	537	1166	1178
Direct & Indirect Impact (2006$)[1]	$173.0 million	$100 million	$283 million	$1,171 million
Employment (jobs)	1,940	1,150	3,180	7,610
Emissions (metric tonnes)	885	602	1,567	2,339
Multiplier on Expenditures[2]	1.47	1.34	1.47	1.61
Multiplier on Employment[3]	3.1	2.1	2.7	6.5

1. 2006$ impacts calculated using deflator of 0.82
2. Multiplier calculated using results from inputs run in 1997$.
3. Multiplier calculated using number of NETL Federal and Contractor employees living in respective state in 2006.

Alternative scenarios were also developed to determine potential impacts under a "buy-local" strategy. The "buy local" strategy assumes that NETL will increase its share of Federal operational expenditures and/or allotment of R&D awards and grants that are spent in or granted to establishments in Pennsylvania and West Virginia. Nine alternative scenarios were defined and represent increasing the local shares of expenditures and/or awards by 50%, 100% or 150% over their current share of total expenditures and awards. The impacts of the scenarios were calculated only for the combined PA and WV region so as to limit the number of scenarios to a reasonable level. Table 2 provides abbreviated results for these scenarios. The bottom two rows in the table show that the resulting multipliers for the combined state region. As expected, the multiplier on expenditures is consistent with the multiplier generated in the baseline scenario (Table 1, column 4). This supports the underlying assumption of linearity that exists in IO models. Because total expenditures and R&D awards were held constant, direct employment is assumed to be unchanged, i.e. changing the state in which expenditures and R&D awards are allocated does not change the number of needed employees. Conversely, increasing the amount of expenditures and R&D awards being injecting into the local economy will spur growth and employment in the region. Therefore, indirect employment increases while direct employment is constant, thus resulting in higher employment multipliers. Detail on assumptions of IO modeling theory is provided in Section V of this report and more details on the inputs and results of these scenarios are available in Section XI.

Table 2. "Buy-Local" Alternative Scenarios in PA/WV Region

Increase in Federal Local Share:	Expenditures: 50%	Expenditures: 100%	Expenditures: 150%	Awards: 50%	Awards: 100%	Awards: 150%	Expenditures and Awards: 50%	Expenditures and Awards: 100%	Expenditures and Awards: 150%
Federal, Contractor and Awards (2006$)	$200 million	$208 million	$215 million	$230 million	$268 million	$305 million	$238 million	$283 million	$328 million
Federal and Contractor Employment (2006 jobs)	1166	1166	1166	1166	1166	1166	1166	1166	1166
Direct & Indirect Impact (2006$)[1]	$294 million	$306 million	$317 million	$339 million	$394 million	$450 million	$349 million	$417 million	$482 million
Employment (jobs)	3,310	3,430	3,560	3,800	4,430	5,050	3,930	4,680	5,420
Emissions (metric tonnes)	1,629	1,691	1,756	1,873	2,176	2,488	1,939	2,305	2,671
Multiplier on Expenditures[2]	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
Multiplier on Employment	2.81	2.91	3.02	3.23	3.76	4.29	3.34	3.97	4.60

1. 2006$ impacts calculated using deflator of 0.82
2. Multiplier calculated using results from inputs run in 1997$.

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Figures

Section I: Introduction

This report documents the development of state-level input-output models for Pennsylvania and West Virginia and the augmentation of the national input-output model with employment data. The models were developed to assess the economic and environmental impacts of expenditures and employment at, and research and development awards originating from, the National Energy Technology Laboratory (NETL) sites located in Pittsburgh, PA and Morgantown, WV.

This project, *National and State Economic and Environmental Impacts of NETL*, is part of the University Partnership program at NETL and the work is conducted via collaboration with Carnegie Mellon University (CMU)[i] and West Virginia University (WVU)[ii].

This project has four major milestones:

1. Extend CMU's existing National Environmental Input-Output (EIO) model to include employment impacts;
2. Construct extended state-level EIO models for Pennsylvania, West Virginia and the combined state region in both MatLab and CMU's interactive web-based model;
3. Define baseline scenarios and exercise the models to estimate baseline impact results;
4. Define alternative scenarios and exercise the models to analyze "what-if" scenarios and to compare the results to the baseline analyses.

The primary goal of this project was to develop a means for routinely estimating state and national economic and environmental impacts derived from NETL employment and activity. The development of this methodology and these models allows NETL to determine its importance with respect to the regional economy. Additionally, sensitivity analyses are now feasible and provide NETL the opportunity to assess ways to increase its positive impact on the local state economies via employment, expenditures and research and development (R&D) awards.

NETL has previously reported impacts of its activities that were estimated using NETL data similar to what was collected for this project. Regional impacts in past analyses used a general multiplier provided by the Department of Commerce. This project extends previous work through the construction of economic models that allow for the calculation of both direct and indirect impacts and by adding employment data. Further, the work conducted through this collaborative effort lays the groundwork for future analysis to be completed using a consistent methodology. The project, whose target audiences are governmental decision makers, industry experts and researchers, also provides these and other users with two easily accessible means – a web-based model and MatLab – to utilize the national and state models for their own environmental and economic impact analysis related to the nation and the states of Pennsylvania and West Virginia.

Section II. Project Scope

As noted, the models developed through this collaboration were created for the purpose of analyzing the impacts of the NETL sites in Pittsburgh, PA and Morgantown, WV. NETL also has sites in Oklahoma, Oregon and Alaska. Models for these sites may be developed in the future, but are outside of the scope of the current project. The data collected from NETL covers fiscal year 2006, the most current data available, and was collected for the following activities:

- Federal expenditures and employment
- Federal R&D award obligations and costs
- Site-support contractor expenditures and employment.

Section III: Key Challenges

Constructing new models for an economic and environmental analysis presents four primary challenges which lead to the identification of several key decision points. The four primary challenges are:

1. Finding quality data sets for economic and environmental parameters;
2. Selecting a methodology for regionalizing the national model;
3. Identifying and collecting NETL data sets;
4. Defining sensible approaches to implementing the model.

The principals guiding the decisions for which data sets to use and which regionalization method to employ were driven by the objective of developing a methodology that is complete, consistent and theoretically sound.

The decision criteria that guide the choices arising from these challenges are outlined below. Additional detail on the data collection, model regionalization and model implementation processes are specified in their respective sections of this document.

Economic and Environmental Data Sets

- Must be consistent with data sources used in the existing national EIO model
- Must be available at the state level for PA and WV
- Must be available for 1997, the year of the most current detailed national IO data

Methodology for Regionalizing the National Model

- Must follow economic principles
- Must be applicable to existing national model construct
- Must be applicable to data used in the existing national model

NETL Data Sets

- Must cover all NETL activities
- Must be available for 2006
- Must identify NETL site and vendor locations

Model Implementation

- Select economic sector(s) best represents NETL
- Determine if all NETL activities will be modeled via a single or via multiple sectors
- Scenario development that sets a baseline for NETL activity

Section IV: Modeling Approach

Environmental input-output models have an implicit assumption that the average relationships between emissions and economic activity, by sector, are indicative of activity in the economy and useful for estimating the economic transactions, employment effects and air emissions impacts from expenditure scenarios.. Further, it is assumed that productivities (output/employment ratios) are constant for any scenarios specified.

This project uses a national economic-input-output life-cycle assessment model developed at Carnegie Mellon and comparable state level models developed for this project. The LCA approach allows us to (1) include *detailed* process-level environmental data as well as *economy-wide* (supply chain) environmental impacts, (2) have environmental and economic information about the *major products and processes* in the economy, (3) *quantify* a *wide range* of environmental data, and (4) *provide policy relevant recommendations* to managers, regulatory agencies, consumers, public policy-makers to help inform environmental, planning, and business decisions. The hybrid approach allows the user to combine models, or choose from several LCA models with more or less detail as the application or time and monetary constraints dictate. At the most detailed level would be the process-level LCA. At the most aggregate end would be the current input-output analysis-based model.

Section V: National Economic Models

The foundation of input-output models is an accounting framework. In this framework, the disposition of industry outputs is represented, and as a double-entry accounting framework, the accounts also detail the sources of inputs to each industry. Because the model is demand driven, we focus on the distribution of outputs for its formulation. Output from an industry can be sold to other industries for further processing, or to final users such as government, consumers, or any destination outside of the region being modeled (exports). Collectively these final users represent final demand. A formal representation of the model is shown below:

$$
\begin{aligned}
&X_1 = z_{11} + z_{12} + \cdots + z_{1j} + \cdots z_{1n} + Y_1 \\
&X_2 = z_{21} + z_{22} + \cdots + z_{2j} + \cdots z_{2n} + Y_2 \\
&\vdots \\
&X_j = z_{j1} + z_{j2} + \cdots + z_{jj} + \cdots z_{jn} + Y_j \\
&\vdots \\
&X_n = z_{n1} + z_{n2} + \cdots + z_{nj} + \cdots z_{nn} + Y_n
\end{aligned}
$$

Where the value of output X_i, is equal to intermediate output z_{ij} that flows from industry *i* to industry *j* plus output delivered to final demand, Y_i. The model is operationalized by assuming that the relationship between industry inputs and the value of industry output is constant over the period of analysis, or $z_{ij} = a_{ij} X_j$, where a_{ij} is a constant for all *i-j* pairs. The above system of equations can then be rewritten as:

$$
\begin{aligned}
&X_1 = a_{11}X_1 + a_{12}X_2 + \cdots + a_{1j}X_j + \cdots a_{1n}X_n + Y_1 \\
&X_2 = a_{21}X_1 + a_{22}X_2 + \cdots + a_{2j}X_j + \cdots a_{2n}X_n + Y_2 \\
&\vdots \\
&X_j = a_{j1}X_1 + a_{j2}X_2 + \cdots + a_{jj}X_j + \cdots a_{jn}X_n + Y_j \\
&\vdots \\
&X_n = a_{n1}X_1 + a_{n2}X_2 + \cdots + a_{nj}X_j + \cdots a_{nn}X_n + Y_n
\end{aligned}
$$

In matrix notation, the system can be written

$$
A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix}, \; X = \begin{pmatrix} X_1 \\ \vdots \\ X_n \end{pmatrix}, \; Y = \begin{pmatrix} Y_1 \\ \vdots \\ Y_n \end{pmatrix}
$$

$$
\begin{aligned}
&X = AX + Y \\
&X - AX = Y \\
&(I - A)X = Y
\end{aligned}
$$

For which the solution for output is

$$(I - A)^{-1} Y = X$$

and $(I - A)^{-1} \Delta Y = \Delta X$

(provided that $|\text{I-A}| \neq 0$,)

These final equations show that total output needed for specified levels or changes in final demands can be computed by pre-multiplying the final demands of interest by a multiplier matrix, commonly referred to as the Leontief inverse.

To recap, input-output models assume:

- that the economy is demand driven meaning that production responds to expressed demand by providing the necessary output for use as inputs.
- perfectly elastic supply (no supply or capacity constraints) within the range of scenarios considered
- fixed linear relationships in production to track final demand stimulated supply chain effects
- that inputs increase in fixed proportion to output increases

For present purposes, particularly at the desired detailed level of disaggregation, there really are no viable alternatives to an IO approach. Although there are other economic models that could be used to generate industry output impacts with which to estimate output-based emissions, all of them would require substantially more resources to implement, if implementation were possible at all. Computable general equilibrium (CGE) models for example, are used to estimate output and other economic impacts of levels or changes in activity, but they are extremely difficult if not impossible to calibrate at the level of detail we have in the model used for this project. While the are few if any viable alternative models,however, refinements to the existing model are possible: including further disaggregation of power and coal mining sectors, or updating to new data (e.g. 2002 data which will become available in late 2007).

The Economic Input-Output Life-Cycle Assessment (EIO-LCA) model developed at Carnegie Mellon provides the capacity to evaluate economic and environmental effects across the supply chain for any of 491 industry sectors in the U.S. economy. The EIO-LCA model also can represent the supply chain use of inputs and resulting environmental outputs across the supply chain by using publicly available data from the U.S. government. By integrating economic data on the existing flow of commerce between commodity sectors with environmental data on releases and material flows generated by each sector, it is possible to estimate the additional environmental emissions caused by an increase in production within a particular sector, accounting for the supply chain. This approach can be used to avoid some of the system boundary limitations of process LCA by drawing upon data for the entire economy. Using the input-output matrix illustrated in Figure 1, the supply chain transactions for a vector of output **y** can be estimated as $\mathbf{x} = [\mathbf{I}-\mathbf{A}]^{-1}\mathbf{Y}$, where **A** is the total requirements matrix constructed by normalizing the **X** matrix in Figure 1 by the sector outputs **X, as shown in the equations above**. With estimates of average sector resource uses and pollution emissions, **E**, the inventory of resource use and emissions associated with the production of **Y** can be calculated as **EX**. The EIO-LCA model includes a variety of such impacts for the entire US economy.

Currently, the EIO-LCA model is in active use. Since 2000, we have had over 900,000 uses of the model (or over 15,000 per month). Of identifiable access sites, educational users are most common, but there is substantial use by government agencies, Non-profit Organizations and companies. A surprising number of foreign users exist, suggesting that international comparisons are of considerable interest. For a closer look at the model, visit http://www.eiolca.net/ on the Internet.

Figure 1. Example Structure of an Economic Input–Output Table

	Input to sectors				Intermediate output *O*	Final demand *Y*	Total output *X*
Output from sectors	1	2	3	n			
1	z_{11}	z_{12}	z_{13}	z_{1n}	O_1	Y_1	X_1
2	z_{21}	z_{22}	z_{23}	z_{2n}	O_2	Y_2	X_2
3	z_{31}	z_{32}	z_{33}	z_{3n}	O_3	Y_3	X_3
N	z_{n1}	z_{n2}	z_{n3}	z_{nn}	O_n	y_n	X_n
Intermediate input *I*	I_1	I_2	I_3	I_n			
Value added *V*	V_1	V_2	V_3	V_n		GDP	
Total input *X*	X_1	X_2	X_3	X_n			

Notes: Matrix entries $\mathbf{z}_{ij}$ are the inputs to sector *j* from sector *i*. Total output for each sector *i*, $\mathbf{X}_i$, is the sum of intermediate outputs used by other sectors, $\mathbf{O}_i$, and final demand by consumers. Gross Domestic Product, GDP, is the sum of all final demands, y_i. Value added for each sector V_j is the difference between total output (equal to total input for each sector) X_j and intermediate input I_j.

Section VI: Regionalizing the National EIO-LCA Model

Comment [LCP1]: need some discussion of why the national model has GHGs and Toxic Releases, but the regional models do not. – Chris should address these.

Economic assessment models typically use product-specific and plant-level or national aggregate data. However, many decisions would be better informed by local or regional data. Such local or regional models may be used to estimate the regional effects of purchases from any of the nearly 500 economic sectors of the US economy.

Input-output models can be constructed for a variety of regional definitions. It is possible, for example, to construct MSA or even county-level IO tables. For this project, we elected to generate state-level tables, for the following reasons. First, no single-county regions would be large enough to capture a significant portion of the economic/environmental impacts in which we are interested. Likewise, models based solely on the Pittsburgh and Morgantown regions would be expected to exclude a large portion of the NETL impacts, and in any event, do not correspond closely to administrative levels at which any relevant policies could be implemented. Further, and importantly, economic and environmental data for increasingly smaller administrative regions are increasingly scarce, and for many of the emissions data completely unavailable, and less comparable across regions. Lastly, the environmental data correspond to industry aggregates at the state and sometimes national level, so might not correspond at all well to industries at smaller geographical levels that do not have a product mix similar to that to which the data correspond.

To generate the regional tables for Pennsylvania, West Virginia, and the Combined (Pennsylvania and West Virginia) region, we used the established location quotient (LQ) method[iii,iv] using the employment vectors described in Section VII below.[v] While the LQ is not as complex as some of the alternatives, its properties are well known and understood, its application is straightforward, and its costs are moderate and hence consistent with the scope of this project.

LQ is a measure with a variety of uses that effectively compares two distributions. In this context, we use the LQ to compare the distribution of employment by industry in a study region and in a reference region. Our study regions are PA, WV and the combined two-state region (PA/WV), while the reference region is the U.S., which is the "region" for which (national) IO data exist. The LQ is calculated as follows:

$$LQ_i = \frac{\left(StateEmp_i / StateEmp \right)}{\left(USEmp_i / USEmp \right)}$$

The LQ regionalization method operates under the assumption that if an industry's share of regional employment equals or exceeds its national counterpart, then it will be able to meet the demand for its output as well as its national counterpart. In this event, the LQ for the industry will have a value greater than or equal to unity (1.0). If an industry's LQ is less than 1.0, it will be less able than its national counterpart to meet the demand for its output. If a regional industry's employment share is, for example, only ½ its national counterpart, then it is assumed to be able to meet only ½ the regional demand for its output.

A second assumption of the LQ method, which is shared by virtually all regionalization methods, is that a national input-output coefficient represents the technical requirements of the j^{th} industry for the i^{th} industry's output, and as such, it is an upper bound value. If we denote the national coefficient by $a_{ij} \in A$, the corresponding regional coefficient by $r_{ij} \in R$, and the location quotient for industry *i* as shown above, then the LQ regionalization procedure can be characterized as

$$r_{ij} \in R = \begin{cases} a_{ij}^N \text{ where } LQ_i \geq 1.0 \\ ------------ \\ a_{ij}^N \left(LQ_i \right) \text{where } LQ_i < 1.0 \end{cases}$$

The resulting regional input-output table, *R*, is a table of regional input coefficients, as compared with the national technical coefficients table, *A*.

Employment, Output or Gross Product
Location quotients can be computed using employment, income, output, or gross product data. We chose employment data primarily because our confidence in the employment data series, which was more complete and consistent with the other data used in this project, was higher than for the alternative. Comparisons of the regional and national employment and GSP data revealed a stronger one-to-one correspondence at the industry level of the BEA IO table.

Irrespective of base data used, no reliable data exist to generate regional values for the public sectors. In all cases, there are either missing data values or irreconcilable sectoral classifications. For these public sectors, the location quotients are assigned values of 1.0 so that the values in the regional coefficients table for these industries will be equal to their values in the national coefficients table, pending more informational data. With no additional information, there is no justification to assume any other regional coefficient values.

Multiplier Analysis
IO multipliers are often used as convenient summaries for purposes of comparing industrial economic structures across regions or nations. Although there are many types of multipliers, the Type I multiplier with households exogenous is most relevant in the present context. A Type I output multiplier for sector *j* is defined as the total (direct and indirect) output from all industries in the region necessary to satisfy a dollar's worth of final demand for regional industry *j*'s output.[vi]

Regional Models Developed for NETL Impact Analysis
For this project, economic, employment and air quality impacts are evaluated at three model levels. The three models, which are available on the web at http://www.eiolca.net/cgi-bin/multimatrix/advindex.pl and in MatLab, include Pennsylvania (PA) and West Virginia (WV) state level models as well as a regional model that is the combination of the two states (PA/WV). MatLab is a high-level language ideally suited for algorithms that involve matrix manipulations. Prototyping for the regional version of the model was carried out in MatLab.

As noted, these models are based on a national economic input-output model adjusted to state or regional production using state economic sector employment to obtain regional economic multipliers and then linking the resulting regional input-output models to state and regional employment and air emissions factors.

The following sections of this report describe the data and methodology used to build the employment and environmental vectors:

- Section VII, *Employment by Sector in Pennsylvania, West Virginia and the United States*, describes the generation of the employment vectors used to estimate the regional input-output models and to estimate the incremental supply chain employment effects of purchases from any of the 491 input-output sectors;
- Section VIII, *Estimation of Air Emissions in Pennsylvania and West Virginia,* describes the data and procedures used to estimate air emissions from the 491 sectors and the development of the air emissions vectors;

Section VII: Employment by Sector in Pennsylvania, West Virginia and the United States[vii]

The EIO-LCA methodology developed at Carnegie Mellon did not include employment; therefore the first step in this effort was to create employment vectors, including national and state level vectors for the 491 sectors.

Data Sources

The models constructed for estimating the economic impact of NETL's Pittsburgh and Morgantown sites are based on the Bureau of Economic Analysis's (BEA) benchmark input-output (IO) accounts. To maintain consistency, the employment vectors created for the national- and state-level models are also based on BEA data. As part of their state personal income reporting, BEA publishes table SA25—"Total Full-Time and Part-Time Employment by Industry."[viii] This table provides employment control levels for this project on an IO-based industry group basis.

BEA's regional division uses data from the Bureau of Labor Statistics' (BLS) Quarterly Census of Employment and Wages (QCEW)[ix] program for 95 percent of its wage and salary employment estimates.[x] The QCEW program provides information on employment and wages for all workers covered by state unemployment insurance (UI) laws as well as Federal workers who are included in the Unemployment Compensation for Federal Employees (UCFE) program.[xi]

To complete their employment data set, BEA supplements the QCEW data with administrative records and collects data for employment that is not covered by UI or UCFE data. These employment areas include railroads, private households, farm labor contractors, private elementary and secondary schools, the military, religious organizations and U.S. residents employed in the United States by international organizations and by foreign embassies and consulates. Additionally, BEA makes industrial and geographic adjustments so the data meet their statistical and conceptual data requirements. The adjustments made to the QCEW data by BEA include adjustments for industry non-classification, misreporting adjustments, adjustments for statewide reporting, adjustments for non-covered segments of UI-covered industries and geographic adjustments for government employment.

Although BEA collects detailed employment data, their publication of these data in table SA25 is aggregated to various levels that, in most cases, do not match the North American Industry Classification System (NAICS) detail provided in the benchmark IO accounts. Thus, the reported employment by industry provided in the national- and state-level versions of the table serve as controls for the detailed employment estimates.

As noted, QCEW data is used for 95 percent of BEA's employment estimates. Furthermore, the QCEW program tabulates employment data at the most detailed NAICS level possible without disclosing proprietary information. These two attributes are the basis for using QCEW data as the foundation for the national and state employment estimates in the NETL impact study. The general process for building employment vectors for the national and state IO models was to download the QCEW data from the BLS FTP server, ftp://ftp.bls.gov/pub/special.requests/cew/, obtain the average annual employment data by NAICS and ownership (private, State government, Federal government), break disclosures where necessary and scale to aggregate industry totals provided by BEA. The details of this process are outlined in the following section.

Steps to Creating Employment Vectors

The first step to building the employment vectors for the national- and state-level IO models is to obtain the QCEW data from the BLS FTP server. The employment data are separated by NAICS and ownership categories. The data for detailed ownership levels, such as Federal, State, and private, were used rather than those for aggregate levels, such as total government, so that discrepancies between the tabulated total and the given control could be identified more easily.

Next, the data must be matched to the NAICS codes used in the 1997 IO accounts. The IO accounts use approximately 491 industry codes, which are representative of NAICS industries at the most detailed level, the 6-digit US industry level,[xii] or are combinations of two or more NAICS industries. The QCEW data, on the other hand, is categorized by the most detailed NAICS code available for the surveyed industry, which can yield a list of nearly 1,200 employment industries. To process such detailed data the first step is to extract the data for those industries in the QCEW data that match the level of detail held in the IO accounts. The remaining data is converted to IO industry codes through a concordance that uses weights to convert the NAICS industries to those IO industries used in the Economic Input Output-Life Cycle Assessment (EIO-LCA) software model.[xiii]

In all sectors except construction, US industry NAICS codes are either represented as the same level of detail in the IO code or are combined to form less-detailed IO industry codes; thus the weights for these conversions are always one. In the construction industry, however, six-digit NAICS codes are split across multiple construction IO codes defined by BEA on an activity-basis. For many construction industries, the mapping of NAICS codes to IO codes is a 1:1 relationship, as in the mapping of NAICS 234120 (Bridge and Tunnel Construction) to IO industry 230230 (Highway, Street, Bridge, and Tunnel Construction). Conversely, other NAICS industries must be split across multiple IO industries, such as NAICS 235110 (Plumbing, Heating, and Air-Conditioning Contractors) which is split to IO industries 230250 (Other New Construction) and 230340 (Other Maintenance and Repair Construction). The splitting weights are calculated by the share of national industry output for each IO industry as published from the 1997 benchmark IO accounts. For example, industry output for 230250 is $68,812 million and industry output for 230340 is $14,389 million. Using these output values, all NAICS industries that are to be split to these two IO industries will be split using weights of 0.827 and 0.173, respectively.

Once all the data are matched to IO industries, summations are made to verify that the total by ownership for all industries matches the total by ownership provided in the QCEW data set. For areas with discrepancies, the data are reviewed for disclosures and the disclosures are broken so that the industry detail sums to the total specified at the next highest level of industry detail.

In some cases, entries for industries are missing. For instance, employment in industry group 2211 (Electric Power Generation, Transmission and Distribution) is 176, but industry-level employment is only provided for industry 22111 (Electric Power Generation) at 97. The discrepancy of 79 employees must be added. In this example there is only one other industry to chose, 22112 (Electric Power Transmission, Control, and Distribution), so the 79 employees are allocated to this industry and the process is complete.

In other cases, there are multiple missing industries. For these instances, two approaches are taken. The first is to apply the entire discrepancy to the industry identified as "other", for example, if there is a discrepancy between the sum of detailed employment and the total employment for 331310 (Alumina and Aluminum Production and Processing), the difference is allocated to US industry 331319 (Other Aluminum Rolling and Drawing). If no "other" industry exists, or if employment is provided for the "other" industry, then the discrepancy is distributed evenly across all missing US industries under an industry code. For example, assume there is a discrepancy between the sum of employment for 331510 (Ferrous Metal Foundries) and the control given for this industry. If employment is only given for US industry 331512 (Steel Investment Foundries), then the discrepancy is split evenly between US industries 331511 (Iron Foundries) and 331513 (Steel Foundries, except Investment).

Note that disclosures are only broken for industries that matched the IO industry list. Disclosures for industries not used in the IO accounts are immaterial, and thus no effort is made to break the disclosures. Once all disclosures are broken, employment is verified by ownership, high-level industry groups identified in the QCEW data, such as Financial Activities and Manufacturing, and overall totals.

The above steps complete the process of converting employment data to IO industries. The data, however, still must be controlled to the employment totals published by BEA in table SA25. Both national- and state-level employment are available for 1997 on a NAICS-basis, so no conversions of the BEA data are required. As noted earlier, the BEA data is aggregated to various agency-defined industry groups, called gross product originating (GPO) industries. Industry codes are assigned to the GPO codes and can be concorded to IO codes through a map provided by BEA.[xiv] The sum of employment by GPO code derived from the QCEW data will not match BEA's employment-by-GPO because of the adjustments BEA makes to the QCEW data and because of the additional employment data BEA compiles to fill the five percent data source gap. Therefore, to reach the BEA employment totals, the QCEW data, on an IO industry basis, is scaled to BEA's GPO total. This method allows the IO industry detail to be preserved while maintaining the employment controls set by BEA.

The method described above is used for all sectors of the economy except agriculture. For that sector, this project follows the methodology used by BEA's Regional Division for the incorporation of farm employment into BEA's Regional Input-Output Modeling System (RIMS) model; total farm employment is allocated to IO industries based on the industry's share of total cash receipts. Cash receipts, which are compiled by the U.S. Department of Agriculture's Economic Research Service (ERS), are downloaded from the ERS Data Sets website for farm income.[xv] The share of cash receipts by IO industry is calculated and applied to total farm employment to estimate farm employment by industry in the employment vectors.

To finalize the employment vectors, a final comparison of industry totals as calculated through this process are compared to the BEA control numbers. Additionally, a comparison is made to the master list of NAICS-based IO industry codes. The national employment vector includes all IO industry codes, so no adjustments are needed. The state-level employment vectors, however, do not include all IO industry codes as not all industries operate within Pennsylvania and West Virginia. The missing industries are added to the state-level vectors with employment set at zero so that these vectors have the same number of rows as the national employment vector and the IO account matrix. This is done so the state-level data can be properly integrated into the models.

Section VIII: Estimation of Air Emissions in Pennsylvania and West Virginia[xvi]

Data Sources

The air emissions vectors for PA, WV, and the PA/WV combined models were created using data from the National Emission Inventory (NEI) compiled by the U.S. Environmental Protection Agency (U.S. EPA). The U.S. EPA Emission Inventory and Analysis Group collects annual emission data from states and local air agencies, tribes, and industries to make the NEI database publicly available on its website.[xvii] The facility summary data set from the 1997 NEI was used to create the criteria air pollutant vectors for the models. It provides emission data for individual facilities and also includes information such as facility name, state, address, and facility SIC, which can be used to convert emission data into the format suitable for input-output model. The following six criteria air pollutants from the NEI data set are included in the models:

- carbon monoxide (CO)
- nitrous oxides (NO_x)
- sulfur dioxide (SO_2)
- volatile organic compounds (VOC)
- particulate matters less than 10-micron in diameter (PM_{10})
- particulate matters less than 2.5-micron in diameter ($PM_{2.5}$)

The facility summary data in the NEI database include only emission data from point source facilities that are required to report their emissions annually to regulatory agencies. It is missing most area sources (non-point and mobile sources) emissions such as dusts from agricultural and construction activities, exhaust from mobile vehicles and non-road engines, and emissions from small industrial or commercial operations not required to submit annual emission report.[xviii] The U.S. EPA estimates non-point source emissions separately in its Tier Reports, which are also available for download from the U.S. EPA's NEI website. However, the Tier Reports do not provide industrial classification information such as SIC (Standard Industrial Classification) or NAICS. There was no reliable way to allocate the area source emissions from the Tier Reports emission categories into SIC or NAICS. Therefore, area source emissions from NEI are not used in creating the criteria air pollutant vectors.

Most relevant industries are included in the NEI database. To account for the area source emissions from a few significant industry groups that do not have reliable emission inventory in the facility summary data set, however, the national EIO-LCA model maintained by Carnegie

Mellon was used to estimate state and regional emissions.[xix] The five 'missing' industry groups include: agriculture (IO sector 11), mining (IO sector 21), energy and municipal water systems (IO sector 22), construction (IO sector 23), and transportation (IO sectors 48 and 49). For these industry groups, the criteria air pollutant emissions from the national model were multiplied by the ratio between gross state products (GSP) and gross national product (GNP) to obtain an estimate of state emissions.[xx] The following formula was used for each IO sector mentioned above:

$$Emissions_{state} = Emissions_{national} \times \frac{GSP_{state}}{GNP}$$

The emissions obtained from this method were used to fill the gaps in the emission vectors obtained from the NEI data. In a few cases where the NEI data set does show emissions for certain sectors in these five industry groups, the larger of the NEI emissions or the estimated emissions from scaling down the national model was used.[xxi] It is important to note that $PM_{2.5}$ emissions were not included in the national model created at Carnegie Mellon because the national EIO-LCA model was created before $PM_{2.5}$ became a criteria pollutant. Therefore, gaps in $PM_{2.5}$ emissions for these five industry groups still exist even after applying the gross product ratio method. The $PM_{2.5}$ emission impacts calculated by the final regional model will under-estimate actual impacts for these five industry groups. Furthermore, for other sectors that emit criteria pollutants that are not part of those five industry groups (mainly manufacturing sectors), fugitive emissions are not included in the model unless the facilities report fugitive emissions in their annual emission report. Non-point fugitive emissions not explicitly covered by point source NEI data or the gross product ratio method are also not included in the model.

Steps to Creating Environmental Vectors

First, the NEI facility summary data set was downloaded from the U.S. EPA website.[xxii] The emissions in Pennsylvania and West Virginia were extracted from the national data set. The total facility emissions were summed by SIC to obtain air pollutant vectors by SIC for each state. For those SIC sectors with no data in NEI, no emissions were assumed and those elements in the vector were set to zero. The unit of each element in these vectors is short tons of pollutant per year.

Second, the SIC-NAICS concordance was applied to these "air pollutant by SIC" vectors to obtain "air pollutant by NAICS" vectors.[xxiii] Due to uncertainties caused by changing sector definitions over the years, several adjustments were made to the former SIC-NAICS concordance to best reflect the sector mapping for the 1997 NEI data. For those sector mappings with significant uncertainties, the facilities comprised of those SIC sectors were reviewed individually to determine their appropriate NAICS. Because U.S. EPA has started to collect NAICS information in more recent years, the 2002 NEI was referenced to determine the appropriate NAICS if these facilities were in operation in 2002. If a facility had ceased operation in 2002 and its NAICS could not be determined using the 2002 NEI, internet research or best judgment were used to determine their appropriate NAICS. In cases where no additional information could be obtained to better inform the SIC-NAICS mapping for these sectors in question, the emissions from SIC were allocated evenly to its corresponding NAICS.

Third, after the "air pollutant by NAICS" vectors were created, the NAICS-IO concordance[xxiv] was applied to obtain air pollutant vectors by IO sectors. These air pollutant vectors were stated in unit of tons of pollutant per year. These air pollutant vectors were stated in unit of short tons of pollutant per year and were subsequently converted to metric tons per year, consistent with the national EIO-LCA model.

Fourth, as described in the previous section, because the NEI facility summary data set is missing most of the emissions from the agriculture, mining, power and water systems, construction, and transportation industry groups, the emission data from the national EIO-LCA model were used to fill the gaps. The national criteria air pollutant emissions in metric tons of pollutant per million dollar output were multiplied by their respective 1997 industry output to obtain metric tons of pollutant emitted by each sector at the national level. The emissions in metric tons were then multiplied by the GSP/GNP ratio to obtain the state emissions for each sector. Next, the resulting emissions for these five industry groups were compared with the NEI emissions where NEI data were available, and the larger of the two was used in the final "air pollutant by IO" vectors.

Finally, after the air pollutant vectors were constructed for Pennsylvania and West Virginia, the 2-state combined vectors were created by summing the emissions of the two states. The final vectors in unit of metric tons per million dollar output were calculated by dividing these air pollutant emissions by their respective sector outputs. For the PA/WV model, the combined emissions were divided by the sum of sector outputs from the two states. The final criteria air pollutant vectors are in unit of tons per million dollar output, and can be used in the regional input-output life cycle assessment model.

Section IX: NETL Data Collection

As per Section I, the goal of this project is to develop a means to estimate national, regional (PA/WV) and state-level (PA and WV) economic and environmental impacts derived from NETL employment and activity. The most current (2006) data was used for input into the model.

The data categories and sources are summarized as follows:

•**NETL (Federal Wages/Salaries and Expenditures)**
The source of the NETL Federal wages and salaries data (calendar year 2006) was the NETL Human Resources Division. Data collected included: number of employees at each duty location, county/state of residence and burden (salary and benefits) by county/state of residence and operational site. The source for expenditures (Fiscal year 2006) was the NETL Site Operations Division. All vendors were identified and aggregated by category (such as 'Laboratory Equipment and Supplies,' 'ADP Software'). The purchasing site and home State for each vendor was also noted.

•**R&D Awards – 2006 Fiscal year (10/01/05 – 09/30/06)**

The source for data related to non-site support contract awards was the NETL Acquisition and Assistance Division and the NETL Financial Management Divison. Data included:

- Award by type: Firm Fixed Price, Cost Plus Fee, Project Grant, etc
- Business type (award recipient): Government, Non-profit organization, Private higher education institute, etc.
- Home state of awardee
- Funding obligated
- Funding costed

Note that 'awards' are not specified to a particular site (Morgantown or Pittsburgh) but include all awards made at all NETL sites. The data that provide award and business type as well as the home state of the award recipient and the obligated funding do not provide detail on the amount costed to NETL. The costed data are provided by the Financial Management Division and are used to prorate the reported obligations.

•Site Support Contractor (Wages/Salaries and Expenditures)
The source for on-site support contractor data was the NETL Site Support Contract Management Team. Targeted requests were sent to each site-support contractor (9 contractors total) and the following information was solicited: wage and salary information, expenditure categories, the site to which the services were provided and the resident state of the vendors. Wage and salary information was based on the 2006 calendar year. Collected data included annual number of employees (based on monthly averages) to which an average fringe benefit rate was applied. Zip code data was used to identify the County/State in which the employees resided. Expenditure data was based on the fiscal year. Some site-support contractors reported that their expenditures are paid directly by NETL and thus did not report expenditures. This, therefore, underestimates the value of NETL's impact related to contractor expenditures.

Section X: Baseline Scenarios and Results

Comment [LCP2]: address comparison of results to real-world knowns.

As an example of the use of the regional input-output models, this section estimates the impacts of NETL expenditures in the nation, Pennsylvania (PA), West Virginia (WV) and the combined area of PA and WV. The steps required to use the model are outlined at the end of this section.

Comment [RWJ3]: This is addressed in table 5

Input-output multipliers will always be expected to differ between regions. This occurs because industry linkages in the supply chains differ in the extent to which supplying and purchasing industries are present within the region for which the model is defined. Regions in which large numbers of suppliers are not present, for example, will have smaller multipliers than regions in which needed inputs can be supplied locally. In effect, the supply chain can be thought of as lying more or less completely within a given region, and this will vary from region to region.

Table 1 shows NETL expenditures by category for the different scenarios for FY 2006. Also shown in Table 1 are the deflated totals of expenditures for 1997. For this purpose, the gross domestic product price deflator was used to convert 2006 $ to 1997 equivalent $[xxv].

The following 'baseline' scenarios were evaluated:

- Scenario 1 - PA/WV MODEL: Impact of both sites (PIT and MGN) on PA/WV region - PA/WV sources, both Pittsburgh and Morgantown sites

- Scenario 2 - WV MODEL: Impact of both sites (PIT and MGN) on WV region - WV sources, both Pittsburgh and Morgantown sites
- Scenario 3 - PA MODEL: Impact of both sites (PIT and MGN) on PA region - PA sources, both Pittsburgh and Morgantown sites
- Scenario 4 - NATIONAL MODEL: Impact of both sites (PIT and MGN) on nation - all source, both Pittsburgh and Morgantown sites

Table 1: Summary of Baseline Scenarios

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
NETL Federal Wages and Salaries ($M 2006)	55.87	23.28	32.58	56.38
NETL Federal Expenditures ($M 2006)	15.19	4.58	10.61	80.84
Contractor Wages and Salaries ($M 2006)	39.79	17.40	22.39	40.19
Contractor Expenditures ($M 2006)	6.25	2.94	3.29	13.58
Awards ($M 2006)	115.46	47.04	68.41	760.40
Sum ($M 2006)	232.55	95.25	137.28	951.38
Sum ($M 1997) (1)	190.69	78.11	112.57	780.13
	PA/WV Model	*WV Model*	*PA Model*	*National Model*

Note
1. Deflating to 1997 $ -- GDP Deflator is: 0.82

NETL expenditures were represented in the input-output model as sector "Scientific Research and Development Services" (NAICS 541700). This representation is consistent with how NETL categorizes itself in governmental reporting and systems such as OSHA reporting, industrial waste surveys and its Industry Interactive Procurement System (IIPS). The US Census Bureau provides the following definition for NAICS 541700:[xxvi]

> *5417 Scientific Research and Development Services*
> This industry group comprises establishments engaged in conducting original investigation undertaken on a systematic basis to gain new knowledge (research) and/or the application of research findings or other scientific knowledge for the creation of new or significantly improved products or processes (experimental development). The industries within this industry group are defined on the basis of the domain of research; that is, on the scientific expertise of the establishment.

The NETL expenditure impacts are shown in Table 2. These results are obtained by multiplying the 1997 Leontief inverse matrix by the 1997 expenditure totals for NETL shown in Table 1 and then multiplying by the various impact vectors. Results are shown for all 4 scenarios, based on 1997 $. Total Direct and Indirect Expenditures have been re-inflated to 2006$.

Comment [LCP4]: Update data on awards.

Comment [LCP5]: Remove note here & clean up rows.

Comment [RWJ6]: I think this is ok now that Chris added a footnote for the source, above?

Comment [LCP7]: Insert endnote on source

Comment [RWJ8]: Again, I think this is addressed in Chris's added endonte

Table 2: Baseline Results (note all are 1997 values unless otherwise noted)

Impact Category	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Direct + Indirect Expenditures ($ M 1997) (1)	281	105	166	1260
Total Direct + Indirect Expenditures ($ M 2006)	343	128	202	1537
Multiplier on Expenditures	1.47	1.35	1.47	1.62
Total Employment (workers)	3850	1460	2280	9,970
SO2 Emissions (metric tonnes)	319	241	139	657
CO Emissions (metric tonnes)	1140	315	669	1490
NOx Emissions (metric tonnes)	301	165	155	530
VOC Emissions (metric tonnes)	104	29.8	61.2	285
Lead Emissions (metric tonnes)	N/A	N/A	N/A	0.147
PM10 Emissions (metric tonnes)	20	8.56	10.5	97.2
PM2.5 Emissions (metric tonnes)	8.44	4.34	4.21	N/A

Note:
1. excludes induced income impacts because households (payments and consumption) are exogenous to the input-output matrix.

Comment [LCP9]: Update results using revised awards data

Comment [LCP10]: Add bottom cells that define the scenario – copy approach used in input table.

The model provides an estimate of total impact as well as a list of the sectors and the magnitude of their respective contributions to the total. In general, the sectors that comprise the largest impacts by category are summarized in Table 3.

Table 3: Impact Categories and Top Sectors for Each

Impact Category	Top Sectors
Total Direct + Indirect Expenditures	
	Scientific research and development services
	Real estate
	Glass and glass products, except glass containers
	Wholesale trade
	Employment services
	Legal
Total Employment (workers)	
	Scientific research and development services
	Employment services
	Wholesale trade
	Services to buildings and dwellings
	Glass and glass products, except glass containers
	Retail trade
	Truck transportation
Environmental Emissions	Truck transportation (1)
	Power generation and supply (2)
	Glass and glass products, except glass containers (3)
	Waste management, agriculture and forestry supply (4)

Notes:
1. Primary source for CO and VOC's
2. Primary source for NOx, SO2 and PM 10
3. Primary source for PM 2.5
4. Primarily seen in national model

Note that the expenditures, when re-inflated to 2006 $, would be higher with a total expenditure of $ 951 M (2006 $) and supply chain expenditures (including direct and indirect economic activity) of $ 1,537 M (2006 $).

Since the input-output models are linear in nature, estimated impacts for larger or smaller NETL expenditures would be linear multiples of the totals shown in Table 2. For example, under the 'National' scenario, a 10% increase in NETL expenditures would be expected to result in an employment increase of 0.1*9970 = 997 workers.

For the sake of comparison, we looked at two other sectors:
- Hospitals: NAICS 622000
- Colleges, Universities and Junior Colleges: NAICS 611A00

For equivalent regional (PA/WV model) expenditures of approximately $191M, the results are shown in Table 4. Note that the expenditure multiplier for hospitals (2.0) is greater than that for colleges (1.87) and NETL (1.47).

Table 4: Comparison of NETL Expenditures to Other Sectors
(note that Comparisons were only run on the combined model of PA/WV)

Impact Category	NETL PA/WV	Colleges	Hospitals
Total Direct + Indirect Expenditures ($ M 1997)	281	293	313
Total Direct + Indirect Expenditures ($ M 2006)	343	357	382
Multiplier on Expenditures	1.47	1.53	1.64
Total Employment (workers)	3850	3880	4890
SO2 Emissions (metric tonnes)	319	296	342
CO Emissions (metric tonnes)	1140	1230	1420
NOx Emissions (metric tonnes)	301	341	328
VOC Emissions (metric tonnes)	104	104	127
Lead Emissions (metric tonnes)	N/A	N/A	N/A
PM10 Emissions (metric tonnes)	20	17	22.7
PM2.5 Emissions (metric tonnes)	8.44	6.6	7.19

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Similarly, we compared NETL impacts to total employment and air emissions for Pennsylvania, West Virginia and the region of PA/WV. The results are shown in Table 5.

Table 5: Relative Impact of NETL Operations (1997)

Impact Category	PA	NETL Relative Impact on PA (%)	WV	NETL Relative Impact on WV (%)	PA and WV	NETL Relative Impact on PA/WV (%)
Total Employment (workers)	6631087	0.034	863155	0.169	7494242	0.051
SO2 Emissions (metric tonnes)	1127725	0.012	669958	0.036	1797682	0.018
CO Emissions (metric tonnes)	1676640	0.040	280996	0.112	1957636	0.058
NOx Emissions (metric tonnes)	752360	0.021	396551	0.042	1148911	0.026
VOC Emissions (metric tonnes)	204542	0.030	46310	0.064	250852	0.042
Lead Emissions (metric tonnes)	N/A	N/A	N/A	N/A	N/A	N/A
PM10 Emissions (metric tonnes)	95306	0.011	31975	0.027	127281	0.016
PM2.5 Emissions (metric tonnes)	27541	0.015	18757	0.023	46298	0.018

Section XI: Alternative Scenarios and Results

Having established a 'baseline', scenarios representing alternative operational strategies of the Morgantown and Pittsburgh facilities were evaluated. Note that the primary categories for data were: NETL wages/salaries and expenditures (or Federal expenditures), R&D awards (Federal awards), and Contractor wages/salaries and expenditures. The following scenarios, defined in conjunction with NETL, serve to evaluate changes in Federal expenditures and R&D awards; no changes were made in the categories of 'Federal Wages/salaries' or 'Contractor Wages/Salaries and Expenditures.' Total, national level expenditures for the Morgantown and Pittsburgh facilities remained unchanged to reflect a constant budget. All scenarios were run on the combined PA/WV regional model in order to evaluate the regional impact of devoting a larger share of expenditures from, and/or granting awards to, entities located in Pennsylvania and West Virginia.

Comment [LCP11]: Provide more context of the constraints on scenario alternatives (be they time, theoretical, etc) and provide a definition of what the scenarios that were run represent.

<u>Alternate Scenarios</u>
Alt Sce A: Increase share of Federal Expenditures in PA/WV region by 50%, all else equal
Alt Sce B: Increase share of Federal Expenditures in PA/WV region by 100%, all else equal
Alt Sce C: Increase share of Federal Expenditures in PA/WV region by 150%, all else equal
Alt Sce D: Increase share of Federal Awards in PA/WV region by 50%, all else equal
Alt Sce E: Increase share of Federal Awards in PA/WV region by 100%, all else equal
Alt Sce F: Increase share of Federal Awards in PA/WV region by 150%, all else equal
Alt Sce G: Increase share of Federal Expenditures & Awards in PA/WV region by 50%, all else equal
Alt Sce H: Increase share of Federal Expenditures & Awards in PA/WV region by 100%, all else equal
Alt Sce I: Increase share of Federal Expenditures & Awards in PA/WV region by 150%, all else equal

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Comment [LCP12]: Update results based on revised awards data.

Table 6: Summary of Alternative Scenarios - Inputs
(note that Alternative Scenarios were only run on the combined model of PA/WV)

	A-Sce A	A-Sce B	A-Sce C	A-Sce D	A-Sce E	A-Sce F	A-Sce G	A-Sce H	A-Sce I
NETL Fed Wages and Salaries ($M 2006)	55.87	55.87	55.87	55.87	55.87	55.87	55.87	55.87	55.87
NETL Federal Expenditures ($M 2006)	22.79	30.4	38.0	15.19	15.19	15.19	22.79	30.39	37.98
Contractor Wages and Salaries ($M 2006)	39.79	39.79	39.79	39.79	39.79	39.79	39.79	39.79	39.79
Contractor Expenditures ($M 2006)	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25
Awards ($M 2006)	115.46	115.46	115.46	173.2	230.9	288.6	173.2	230.91	288.6
Sum ($M 2006)	240.15	247.74	255.34	290.28	348.01	405.74	297.88	363.20	428.53
Sum ($M 1997)	196.92	203.15	209.38	238.03	285.37	332.70	244.26	297.82	351.39

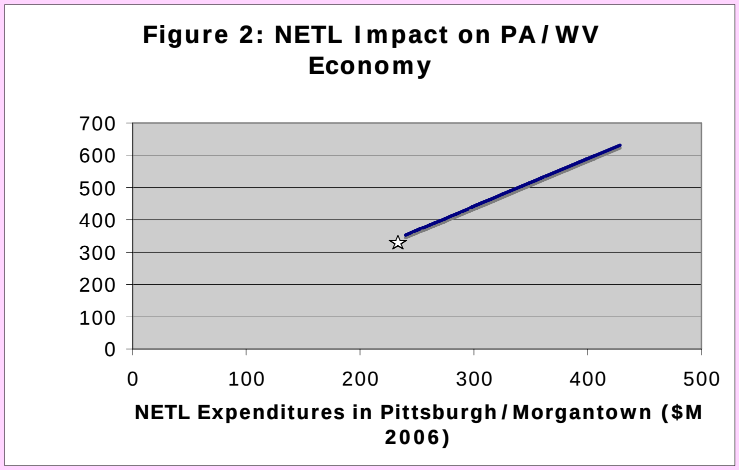
The results of the scenario analysis are summarized in Table 7. The multiplier for the regional model (as noted in the baseline analysis) is 1.47 therefore, for every $1M of NETL expenditures that remain with in Pennsylvania and West Virginia, the regional economy grows by $1.47M. Similarly, employment increases by about 20 persons for each $1M that remains in the region.

Table 7: Summary of Alternative Scenarios – Results (in 1997 values unless otherwise noted)

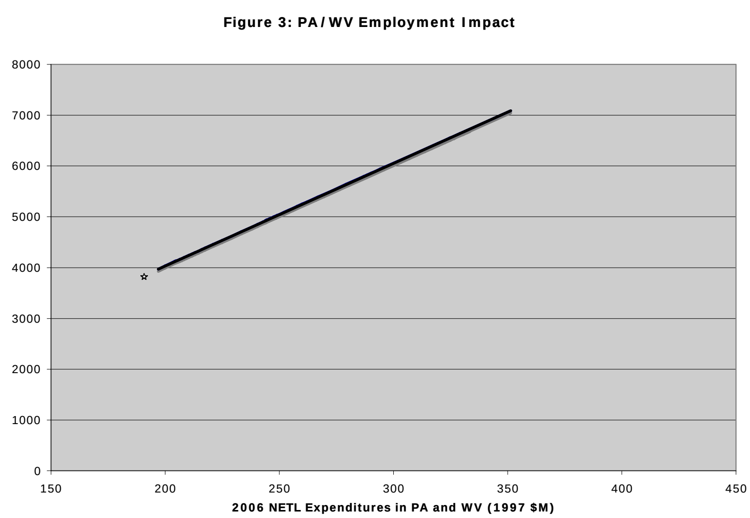
Comment [LCP13]: Update results based on revised awards data.

	A-Sce A	A-Sce B	A-Sce C	A-Sce D	A-Sce E	A-Sce F	A-Sce G	A-Sce H	A-Sce I
Total Direct + Indirect Expenditures ($ M 1997)	290	299	308	350	420	490	360	439	517
Total Direct + Indirect Expenditures ($ M 2006)	354	365	376	427	512	598	439	535	630
Multiplier on Expenditures	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
Total Employment (workers)	3970	4100	4220	4800	5760	6710	4930	6010	7090
SO2 Emissions (metric tonnes)	329	340	350	398	477	556	408	498	588
CO Emissions (metric tonnes)	1180	1220	1250	1420	1710	1990	1460	1780	2100
NOx Emissions (metric tonnes)	310	320	330	375	450	525	385	470	554
VOC Emissions (metric tonnes)	108	111	114	130	156	182	134	163	192
Lead Emissions (metric tonnes)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PM10 Emissions (metric tonnes)	20.6	21.3	21.9	24.9	29.9	34.8	25.6	31.2	36.8
PM2.5 Emissions (metric tonnes)	8.68	8.96	9.23	10.5	12.6	14.7	10.8	13.1	15.5

The relationship between NETL expenditures and regional economic impacts is shown graphically in Figure 2. As noted above, the multiplier is 1.47.



The relationship between NETL expenditures originating from the Morgantown and Pittsburgh sites and regional employment is shown graphically in Figure 3. Note that approximately 20 new jobs are created for every $1M in expenditures.



Comment [LCP14]: In Figures 2 and 3, define the y-axis, make sure both are using 1997$ and that the x-axis is "... in PA/WV ...."

Comment [RWJ15]: Both in same dollars, relationship (slope) would be the same either way

Let's discuss these two graphs Tuesday.

How to Use the Model

1. Go to: www.eiolca.net
2. Click on the tab labeled: 'Use the Model'
3. Click on the tab labeled 'Custom'
4. Click on the tab labeled ' Advanced'
5. Go to 'Available Models,' make a selection, then click on 'Browse' to confirm your selection
6. While on the same page, go to 'Categories,' select 'Professional and Technical Services,' then click on 'Browse' to confirm your selection
7. From the 'sector' menu, select 'Scientific and Development Services'
8. While on the same page, select the 'data source'
9. While on the same page, enter the level of economic activity to be analyzed

Section XII: Project Strengths and Areas for Improvement

The project team of NETL, Carnegie Mellon and West Virginia University has successfully added an employment vector to an existing national EIO-LCA model and has created the first regional-level EIO-LCA model that addresses economic activity, employment and air emissions. Additionally, a web-based model as well as a MatLab model have been created, both of which are expandable. The project was also successful in meeting the goal of developing useable tools to evaluate the impacts of Morgantown- and Pittsburgh-based NETL activities on Pennsylvania, West Virginia, the combined region of Pennsylvania and West Virginia, and the nation.

The models could be more robust if more than one sector (NAICS 5417) was used to define NETL expenditures. The challenge here is to determine which sectors are most appropriate for disaggregating the input data and ensuring the effort is justified by the output of meaningful results (the sectors must truly reflect a difference in operational outputs). Similarly, disaggregating input data will allow for the identification of areas for improvement. For instance, if we could disaggregate the power sector to reflect alternative fuel types, we may be able to access the impact of reducing consumption of energy produced by the burning of fossil fuels.

For future analyses, developing a formal data request process should be developed. Establishing a formal process would decrease the amount of time allocated to collecting federal and contractor data on salaries, expenditures and awards. Additionally, more effort is needed to obtain the detailed data needed to conduct more granular impact analyses at the state and regional level and to correct for data gaps that exist in the current analysis.

Comment [RWJ16]: Lisa: it isn't clear to me exactly what you are describing/requesting here.

Section XIII: Future Steps

Future steps should be addressed in tiers:

Tier 1

- Update the models to run on 2002 economic and environmental data (as opposed to the 1997)
- Define NETL activities using more than one sector
- Update the web version to give higher visibility to the NETL-specific models

Tier 2

- Create a visualization tool/interface that increases the ease of use
- Parse the power sector data to understand the impacts related to the use of alternative fuels
- Develop stand-alone MatLab executable

Tier 3

- Advance the models to be able to evaluate the regional and national impacts (economic and environmental) of deployed technologies that have been developed by NETL researchers

Section XIV: Summary

Tables

Table 1. ***Top 20 Output Multipliers by Industry for Pennsylvania***

I-O Code	Industry Name	PA Multipliers
311512	Creamery butter manufacturing	2.9963
331411	Primary smelting and refining of copper	2.9243
311513	Cheese manufacturing	2.8872
311511	Fluid milk manufacturing	2.7679
331421	Copper rolling, drawing, and extruding	2.6563
311611	Animal, except poultry, slaughtering	2.653
S00201	State and local government passenger transit	2.6452
316100	Leather and hide tanning and finishing	2.6406
331422	Copper wire, except mechanical, drawing	2.6136
311612	Meat processed from carcasses	2.5561
321114	Wood preservation	2.5413
331221	Rolled steel shape manufacturing	2.5198
311615	Poultry processing	2.4761
332430	Metal can, box, and other container manufacturing	2.4071
322225	Flexible packaging foil manufacturing	2.3972
334300	Audio and video equipment manufacturing	2.3551
112100	Cattle ranching and farming	2.3484
525000	Funds, trusts, and other financial vehicles	2.3472
325991	Custom compounding of purchased resins	2.3452
336211	Motor vehicle body manufacturing	2.345

Table 2. ***Top 20 Output Multipliers by Industry for West Virginia***

I-O Code	Industry Name	WV Multipliers
331411	Primary smelting and refining of copper	2.8448
321114	Wood preservation	2.5749
331421	Copper rolling, drawing, and extruding	2.5205
311611	Animal, except poultry, slaughtering	2.5128
331319	Other aluminum rolling and drawing	2.5107
331422	Copper wire, except mechanical, drawing	2.3468
331315	Aluminum sheet, plate, and foil manufacturing	2.3337
321912	Cut stock, resawing lumber, and planing	2.3324
332430	Metal can, box, and other container manufacturing	2.3154
311511	Fluid milk manufacturing	2.2865
331316	Aluminum extruded product manufacturing	2.2251
321918	Other millwork, including flooring	2.2249
331311	Alumina refining	2.2039
331312	Primary aluminum production	2.2027
312210	Tobacco stemming and redrying	2.1955
324110	Petroleum refineries	2.1939
321113	Sawmills	2.173
325312	Phosphatic fertilizer manufacturing	2.1589
321920	Wood container and pallet manufacturing	2.1565
112100	Cattle ranching and farming	2.1542

Table 3. ***Output Multipliers for Combined Region (PA/WV)***

I-O Code	Industry Name	Comb. Multipliers
311512	Creamery butter manufacturing	3.0304
331411	Primary smelting and refining of copper	2.941
311513	Cheese manufacturing	2.8911
311511	Fluid milk manufacturing	2.8311
S00201	State and local government passenger transit	2.7395
311611	Animal, except poultry, slaughtering	2.7393
321114	Wood preservation	2.6965
331421	Copper rolling, drawing, and extruding	2.6649
331422	Copper wire, except mechanical, drawing	2.6254
316100	Leather and hide tanning and finishing	2.6202
311612	Meat processed from carcasses	2.5284
331221	Rolled steel shape manufacturing	2.5271
311615	Poultry processing	2.5132
332430	Metal can, box, and other container manufacturing	2.4927
325110	Petrochemical manufacturing	2.4778
112100	Cattle ranching and farming	2.4720
331311	Alumina refining	2.4702
325211	Plastics material and resin manufacturing	2.4617
324121	Asphalt paving mixture and block manufacturing	2.4592
322225	Flexible packaging foil manufacturing	2.4422

Table 4. ***Comparison of the Output Multipliers and Rankings in the 3 Different Regions***

I-O Code	Industry Name	Combined Multipliers	Rank C		WV Multipliers	Rank WV		PA Multipliers	Rank PA
311512	Creamery butter manufacturing	3.0304	1		-	-		2.9963	1
331411	Primary smelting and refining of copper	2.941	2		2.8448	1		2.9243	2
311513	Cheese manufacturing	2.8911	3		-	-		2.8872	3
311511	Fluid milk manufacturing	2.8311	4		2.2865	10		2.7679	4
S00201	State and local government passenger transit	2.7395	5		-	-		2.6452	7
311611	Animal, except poultry, slaughtering	2.7393	6		2.5128	4		2.653	6
321114	Wood preservation	2.6965	7		2.5749	2		2.5413	11
331421	Copper rolling, drawing, and extruding	2.6649	8		2.5205	3		2.6563	5
331422	Copper wire, except mechanical, drawing	2.6254	9		2.3468	6		2.6136	9
316100	Leather and hide tanning and finishing	2.6202	10		-	-		2.6406	8
311612	Meat processed from carcasses	2.5284	11		-	-		2.5561	10
331221	Rolled steel shape manufacturing	2.5271	12		-	-		2.5198	12
311615	Poultry processing	2.5132	13		-	-		2.4761	13
332430	Metal can, box, and other container manufacturing	2.4927	14		2.3154	9		2.4071	14
325110	Petrochemical manufacturing	2.4778	15		-	-		-	-
112100	Cattle ranching and farming	2.4720	16		2.1542	20		2.3484	17
331311	Alumina refining	2.4702	17		2.2039	13		-	-
325211	Plastics material and resin manufacturing	2.4617	18		-	-		-	-
324121	Asphalt paving mixture and block manufacturing	2.4592	19		-	-		-	-
322225	Flexible packaging foil manufacturing	2.4422	20		-	-		2.3972	15
331319	Other aluminum rolling and drawing	-	-		2.5107	5		-	-
331315	Aluminum sheet, plate, and foil manufacturing	-	-		2.3337	7		-	-
321912	Cut stock, resawing lumber, and planing	-	-		2.3324	8		-	-
331316	Aluminum extruded product manufacturing	-	-		2.2251	11		-	-
321918	Other millwork, including flooring	-	-		2.2249	12		-	-
331312	Primary aluminum production	-	-		2.2027	14		-	-
312210	Tobacco stemming and redrying	-	-		2.1955	15		-	-
324110	Petroleum refineries	-	-		2.1939	16		-	-
321113	Sawmills	-	-		2.173	17		-	-
325312	Phosphatic fertilizer manufacturing	-	-		2.1589	18		-	-
321920	Wood container and pallet manufacturing	-	-		2.1565	19		-	-
334300	Audio and video equipment manufacturing	-	-		-	-		2.3551	16
525000	Funds, trusts, and other financial vehicles	-	-		-	-		2.3472	18
325991	Custom compounding of purchased resins	-	-		-	-		2.3452	19
336211	Motor vehicle body manufacturing	-	-		-	-		2.345	20

1.3.2.2 Economic-based LCA Approach

Comment [RWJ17]: I'm not sure who added this or just where it belongs, and likewise for the next section….

Input-output (IO) models were originally developed in the 1930s by the Nobel Prize winner Wassily Leontief. An economic IO table is a matrix of dollar flows among sectors of an economy, which can represent total sales from one sector to another, purchases from one sector, or the amount of purchases from one sector to produce a dollar of output for the sector.

For example, the input to the EIO-LCA model is an increment of demand into the economy (e.g., a $20,000 car) and the output is a summary of the purchases from all sectors in the supply chain needed to produce the car. Both direct emissions from assembly plants and indirect emissions from the total supply chain (e.g. glass, plastic, steel manufactures) are included in the results. The EIO-LCA model is linear, thus the impacts from production of a $40,000 car will be uniformly double those of a $20,000 car. EIO-LCA is considered a "top down" approach to life cycle assessment.

The EIO-LCA model represents the supply chain use of inputs and resulting environmental outputs by using publicly available data sources from the U.S. government. The model is based on the 1997 Benchmark IO tables, which are the most recent currently available (2002 tables will be available in late 2007), using 491 sectors to represent the U.S. economy. The overall impact of the age of the data has been demonstrated in previous EIO-LCA studies to have minor impacts on mature industries, such as power generation and steel manufacturing. However, results for newer and rapidly changing industries, such as computer manufacturing, will be more strongly affected by the age of the data set.

The EIO-LCA model includes a variety of such impacts for the entire US economy:

Releases of conventional pollutants: SO_2, CO, NO_2, VOCs, PM10 [EPA AirData].

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Toxic releases: estimate of toxic materials released by the supply chain during production [EPA Toxics Release Inventory].

Global warming: estimate of greenhouse gases (CO_2, CH_4, N_2O and CFCs) released into the air during the production and global warming potential [EPA].

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Energy: estimated fuel consumption associated with production across the supply chain [DOE MECS Data].

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Results for greenhouse gases and criteria pollutants were used to evaluate environmental impacts for this study; the EIO-LCA model does not contain water use or consumption data. Emissions were quantified by mapping components for each of the life cycle stages to appropriate sectors in the model. For example, pipeline transport of hydrogen was mapped to the 'pipeline transportation' sector. The construction and operation costs used as inputs to the model were determined through the life cycle cost analysis. The limitations to using the EIO-LCA model to analyze future technologies are discussed in Section 1.4.

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[i] Principal Investigators from CMU: Deborah Lange and Christopher Hendrickson, Steinbrenner Institute for Environmental Education and Research.
[ii] Principal Investigator from WVU: Randall Jackson, Regional Research Institute.
[iii] Hewings, Geoffrey J.D. (1985). Regional Input-Output Analysis. Beverly Hills: Sage Publications.
[iv] Miller, Ronald E. & Peter D. Blair. (1985). *Input-Output Analysis: Foundations and Extensions.* Englewood Cliffs, NJ: Prentice Hall.
[v] A wide range of methods for the construction of regional input-output (IO) tables exists. The methods include extremely costly (and rare) full-survey methods, methods that rely entirely on secondary data to adapt national IO data to reflect the industry structure of regional economies, and hybrid methods that combine primary and secondary data. Among these "regionalization" methods, a further variety exists. Among others, analysts employ supply-demand pool techniques, econometric methods, and location quotient techniques. Each of these has its unique advantages and disadvantages, including data requirements, time and effort required, and associated costs of implementation.
[vi] Miller, Ronald E. & Peter D. Blair. (1985). *Input-Output Analysis: Foundations and Extensions.* Englewood Cliffs, NJ: Prentice Hall.

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[xiv] Bureau of Economic Analysis, "Input-Output Accounts Data: Annual Tables," http://www.bea.gov/bea/dn2/i-o_annual.htm (accessed December 8, 2006).
[xv] Economic Research Service, "ERS/USDA Data—Farm Income," http://www.ers.usda.gov/data/farmincome/finfidmu.htm (accessed December 16, 2006).
[xvi] This section of the report and the estimation of the air emissions vectors were led by Anny Huang, Carnegie Mellon University.
[xvii] U.S. EPA National Emission Inventory data are available at: http://www.epa.gov/ttn/chief/net/.
[xviii] Information about various source categories in NEI is available at: http://www.epa.gov/oar/data/neidb.html.
[xix] Carnegie Mellon University, Economic Input-Output Life Cycle Assessment (EIO-LCA) model, http://www.eiolca.net

[xx] National criteria air pollutant emissions were obtained from the EIO-LCA model website, http://www.eiolca.net. GSP and GNP values were obtained from applying an allocation method to the data from Bureau of Economic Analysis of the U.S. Department of Commerce. For allocation methodology, see: Gyorgyi Cicas, "Regional Economic Input-Output Analysis-Based Life-Cycle Assessment," Ph.D. thesis, Carnegie Mellon University, 2006.

[xxi] The larger value of the two different methods was used because it provides a more conservative estimate.

[xxii] Facility summary data set of 1997 NEI is downloaded from: ftp://ftp.epa.gov/pub/EmisInventory/nei_criteria_summaries/1997criteriasummaryfiles/ (accessed: February 13, 2007).

[xxiii] SIC-NAICS concordance used in Gyorgyi Cicas's Ph.D. thesis, "Regional Economic Input-Output Analysis-Based Life-Cycle Assessment," Carnegie Mellon University, 2006.

[xxiv] As described in Section 2.

[xxv] Gross Domestic Product indexes are available in the Statistical Abstract of the United States. See http://www.census.gov/prod/www/statistical-abstract-1995_2000.html

[xxvi] NAICS codes are described in the NAICS Census homepage: http://www.census.gov/epcd/www/naics.html (accessed July 5, 2007).