Project Methodology & Model Implementation Plan
EPAct Project:
Valuing Domestically Produced Natural Gas and Oil

DOE/NETL-404.03.02/100608

October 6, 2008

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Contract Information: 404.03.02

Acknowledgements

This work is funded by the U.S. Department of Energy's National Energy Technology Laboratory (U.S. DOE-NETL). The NETL sponsors for this project are John Duda, Director of NETL's Strategic Center for Natural Gas and Oil, and Joseph P. DiPietro, Task Manager for the Office of Systems, Analysis and Planning (OSAP). Kristin Gerdes of OSAP provided valuable information and guidance related to well, plant and pipeline construction costs. The NETL management team provided guidance and technical oversight for this study. The authors acknowledge the significant role played by U.S. DOE/NETL in providing the programmatic guidance and review of this report.

The participation of the following individuals, who served as merit reviewers for the methodology of this project, is gratefully acknowledged: Dr. Larry Leistritz (North Dakota State University), Thomas Murphy (Penn State), Scott Rotruck (Chesapeake Energy), David Taylor (University of Wyoming) and Kent Perry (GTI).

Section 1: Objective, Scope, and Key Assumptions of the Impact Analysis Project

1.1 Objective

In August 2005, President Bush signed the Energy Policy Act of 2005 (EPAct) into law; EPAct was the first national energy legislation in more than a decade. EPAct Sections 965, 968, and 999 all support oil and gas research and development (R&D). Sections 965 and 968 relate to programs that the Department of Energy's (DOE) Office of Fossil Energy and the National Energy Technology Laboratory (NETL) are already implementing. Section 999 (EPAct 999), however, adds a new dimension to the overall DOE oil and gas R&D effort, enhancing opportunities to demonstrate ultra-deepwater and unconventional technologies in the field and accelerate their implementation in the marketplace[1]. In addition to the direct support of technology development, Section 999 also provides for benefits and impact analyses to be conducted in support of the technology development programs.

Technologies supported and advanced by EPAct 999 funding are expected to increase United States natural gas and oil production while lowering production costs. The goal of this project is to develop a model that will facilitate a national and regional economic analysis of the potential impacts of offsetting imports by increasing domestic natural gas and oil production in areas likely to be impacted by this research and development program. Because this project is being conducted prior to the development of EPAct 999-related technologies, it does not intend to capture the impact of deploying new, potentially game-changing technologies into the market. Rather, this analysis intends to serve as a baseline of potential impacts that could be derived using present-day technologies.

Ultimately, this project is aimed at capturing the economic impacts of industry-based activity associated with converting new and existing reserves into production and moving this product to the point of refinement or processing. In the case of natural gas, processing is included within the scope of this project. The incremental value of these activities is defined as the net value of the new domestic production activities less the value of imported supply activities within the United States.[2]

This research is distinguished from other research efforts in three major dimensions. First, this project rests on a foundation of comprehensive oil and gas production and demand data specific to five primary production basins. Model data are drawn from a wide range of sources and compiled under a comprehensive framework. Second, this project conjoins the foundation data

[1] NETL, 2007, p. 10.

[2] Earlier definitions of incremental value included the possibility of incorporating an aspect of loss of economic activity associated with imports handling activities such as operation and maintenance of liquefied natural gas (LNG) facilities, natural gas pipelines and port off-loading of crude oil. Subsequent research, however, suggests they not be incorporated for two reasons. First, many of the related imports handling activities are insubstantial, such as coupling a pipeline connector and throwing a switch. Activity levels this small, in and of themselves, are effectively beyond the accuracy of most macroeconomic models, and would be completely overwhelmed by the positive impacts of increased domestic production. Second, even if the associated direct impacts were more substantial, there is effectively no data available with which to quantify them.

above with a macroeconomic modeling framework at both national and sub-national regional scales. Third, the method of modeling import substitution developed and implemented in this project differs from previous approaches, both by design and of necessity given the focus on sub-national regional economic impacts.

1.2 Scope

The scope of the project is the economic analysis of regional and national direct, indirect and induced impacts of the substitution of domestic oil and natural gas production for imports on a variety of economic factors, including output, jobs, income and Federal and State taxes. Additionally, if possible, the model will estimate level changes to total governmental spending (due to increased tax and/or royalties revenue[3]) and consumer expenditures. This analysis will be conducted for five state or multi-state sub-national regions and for the United States as a whole. Detailed discussion concerning the selection of the sub-national regions can be found in Section 4.0.

This project is focused on capturing the incremental, comparative value of replacing imports with domestically sourced on-shore oil and natural gas in various regions of the United States as well as in the national context. Because the goal of this project is specific, the project must employ scope boundaries. Therefore, a critical decision point in this project is the determination of what will and will not be included in the model and the resulting analysis.

For both natural gas and oil, the project boundary encompasses raw material extraction and transmission of this raw material to a processing facility. It is acknowledged that increased domestic production of natural gas and oil may overwhelm existing transportation modes that move supply from the new or existing extraction sources to the processing site. Therefore, the analysis will incorporate pipeline construction costs on a per well and average distance basis[4].

A primary assumption of this project is that additional domestic production is displacing current dry natural gas and crude oil production in a 1:1 ratio. Therefore, new transportation infrastructure is not expected to be required to move processed natural gas or processed crude oil out of a refinery. Should such infrastructure be required by the region, this impact is not captured within the boundary of this project. The existing transportation system (pipelines, trucks, etc.) will be analyzed to determine if additional resources would be needed to satisfy only the movement of natural gas to a processing plant and crude oil to the gathering line collection station[5]. The costs of land acquisition and subsequent impacts on real estate and development values, however, lie beyond the project scope.

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[3] Royalties revenue will not be calculated as part of this project. Should royalties revenue be reported with this project's results, they will be an exogenous input from the presently on-going DOE/NETL project 402.02.01 – *RPSEA Benefits and Model Development*.

[4] Operation and maintenance (O&M) costs for pipelines are embedded into the production function of the natural gas and oil extraction industry and therefore will automatically be captured in the analysis of increased production.

[5] Data required to incorporate pre-processing transportation impacts include, but may not be limited to, existing refinery and pipeline capacity locations and utilization rates and distinct construction and O&M costs. Consideration of impacts on the trucking industry may be limited to capacity additions in the form of demand for additional tanker

Because domestically produced natural gas is often times less pure than imported natural gas, it is important to include the gas processing facility within the boundary of the project[6,7]. A portion of marketed natural gas does not require processing and is sent straight to the transmission and distribution system. Pipelines that move unprocessed natural gas to end users are outside the scope of this project.

For the purposes of this study, we assume that domestically produced crude oil is immaterially different from imported crude oil with respect to the amount of processing required and thus is processed with the same level of ease or difficulty as current imported volumes. This assumption supports the exclusion of refineries from the project boundary. Shipments of crude oil from the field to a collection station, however, are still within project bounds. Pipelines that move crude oil from a collection station to the refinery are outside the project boundary.

Once natural gas is cleaned at a processing plant or crude oil is refined at a petroleum refinery, these products are considered ready for distribution to end-users. At this point in the life cycle of natural gas and oil, no distinction is made between domestic and imported supplies. Therefore, because shifting supply from imported to domestic sources has no bearing on the post-processing system, the transportation system that moves supply from the processing site to the end-user is not within the system boundary.

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trucks and possibly the fuel demand. Modeling the impacts of increased truck transportation comprehensively can be an exceedingly complex process, the majority of which lies beyond the scope of this project.

[6] Gas-processing plants yield by-products that can be sold and thus increase total gas processing industry output. This output will be higher when domestic natural gas production increases because imported LNG has been processed prior to shipment to remove negative impurities

[7] Imported LNG is received at pipeline quality and does not require further processing at domestic natural gas processing plants.

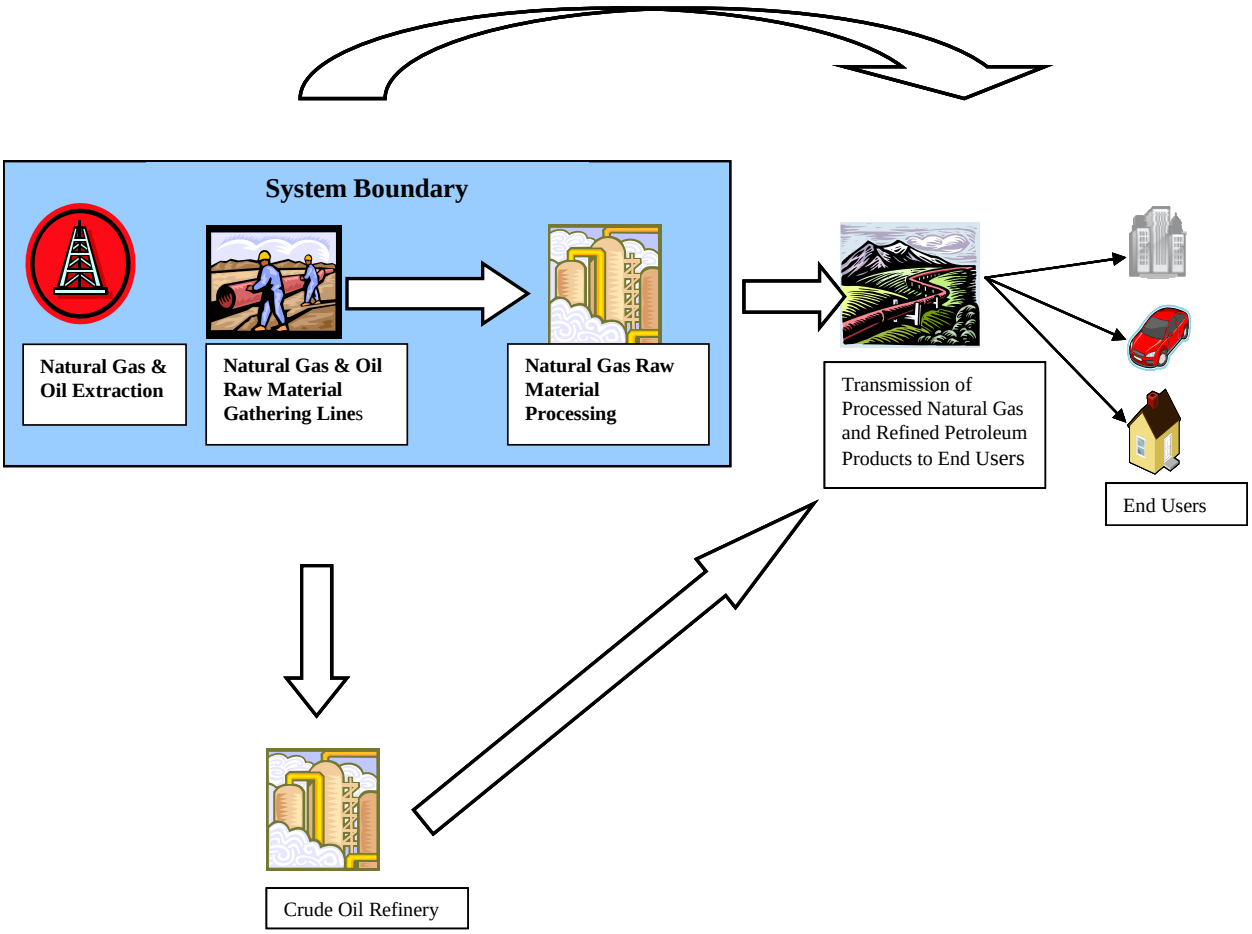

Figure 1: System & System Boundary for Valuing the Incremental Value of Producing Natural Gas & Oil Domestically

The scope of this project is also bounded by assumptions on supply displacement. In the model constructed and the subsequent analysis, it is assumed that domestic production will only displace natural gas imported via pipelines or as liquefied natural gas (LNG) and crude oil and will not impact refined oil product imports. A review of major project assumptions is provided in Section 1.3.

The project will also incorporate an element of time. EPAct 999 activities begin in 2007, though many of the technologies aimed at increasing domestic production are not expected to become commercially available until after 2008. However, this project is focused on impacts of increasing production in regions that are home to resources targeted by EPAct 999, such as unconventional natural gas and oil reserves and, as noted above, does not attempt to estimate the impacts derived from EPAct 999 technologies, per se. Although EPAct 999, in part, focuses on the development of technologies for use in ultra-deep water (UDW) extraction, impacts of

increased production from UDW activities are not analyzed in this study due to project resource constraints. There is, however, a potential area for future work following the demonstration of the methodology developed here for on-shore production impacts. The analysis conducted through this project covers increased production that begins prior to EPAct technology deployment. As a result, analysis scenarios could be based on projected EPAct-related production increases, but cannot be based on related impacts as determined by technology-bases assessments. At a minimum, the project's scenario impact analysis report, planned for December 2008, will present an analysis of incremental production impacts for the years 2010 and 2030. Provided sufficient data, the analysis may be extended to the year 2050.

As an additional point, effects on prices and behavioral responses to relative price changes lie outside the project system boundary. Further, electric power industry employment and output data are typically reported for the industry as a whole. It is reasonable to assume that changes in fuel prices due to increased domestic fuel production would lead to shifts in electric generation shares from one fuel to another, potentially leading to impacts on end-user average electricity prices. However, given the level of industry aggregation, the shift in generation shares would occur within the same aggregate sector, thus no impact could be detected. Impacts on end-user average electricity prices therefore will not be captured.

1.3 Design Parameters and Assumptions

This section provides information on various components of the study process and model design that must be clearly defined to ensure that the goals of the project are met. Some study parameters are, however, discussed in other sections of this report. Specifically, Section 1.2 names the economic variables that will be analyzed by the model. Section 4.0 discusses the geographic level of detail that will be used in this study and presents map-based presentations of the project's analysis regions. Appendix B defines the industry detail that is maintained in the model. Lastly, a list of preliminary data sources is presented in Section 5.0 while Section 6.0 discusses the project methodology and Section 7.0 reviews the model construction and calculation methodology.

This project incorporates several assumptions into the study design. These assumptions impact the results and should be taken into consideration when analyzing, interpreting and applying the results generated from the project model.

To isolate the value of increasing domestically produced natural gas and oil, a primary assumption is that increased domestic production replaces imported supplies in a volumetrically one-to-one relationship, therefore leaving the total supply of energy resources within a region and/or the United States unaffected by increased domestic production.

Specifically, the modeling approach assumes that:

- domestic crude displaces imported crude only
- domestic crude is materially equivalent to imported crude in terms of processing requirements

- domestic natural gas displaces imported LNG and pipeline imports[8]
- new regional production will be used within the region to the extent that the region is under-supplied; beyond this point new production will be exported beyond the region's borders in proportion to the existing export destination distribution

Average transportation distances will be applied to the analysis to facilitate the calculation of required pipeline distances for new and displaced oil and natural gas supplies. These averages were developed during the course of the project and are based on a review of available data and literature.

This project's researchers recognize that oil and natural gas supplies are often purchased from suppliers through long-term contracts. Therefore, to accommodate the injection of new domestic supply and the displacement of imports, it is assumed that a significant portion of imported supply is held under short- to medium-range contracts such that new domestic supply can displace imports without causing implied contractual infractions.

It is assumed that resources exist to meet employment, material and service demand of increased domestic production. Other assumptions consistent with the economic input-output modeling framework will be adopted for this analysis.

The output of the model will be in monetary terms. It is expected that all output will be in 2006 constant dollars, which is consistent with the model's input data. If, and as needed, deflators will be based on IMPLAN[9] data.[10]

Section 2.0 Comparison to Other Production Impact Studies

Agencies such as the Interstate Oil and Gas Compact Commission (IOGCC) and the Independent Petroleum Association of America (IPAA) conduct single year studies on the economic activity and resulting economic impacts of activity within the oil and natural gas industries. While the project outlined in this report addresses issues within the same problem domain as research reported in the IOGCC and IPAA reports, this project aims to complement and expand the information and insights provided by these reports and does not intend to duplicate these external efforts. This project quantifies the impacts of import substitution a) with a different geographical breakdown and coverage, and b) using a fundamentally different methodological approach than the studies accessed and reviewed to date. Without exception, the studies reviewed use final demand-based estimates to drive their assessment models. The approach used here relies more directly on table editing procedures that emphasize the impacts of domestic output changes rather than changes in final demand (although the latter also enter into our analyses, as described in greater detail in later sections).

[8] Energy Information Administration (EIA) data show that none of the sub-national regions currently import LNG and only California has LNG exports.
[9] IMPLAN (IMpact analysis for PLANning) is an input-output based analysis framework produced by the Minnesota IMPLAN Group (MIG), Inc.
[10] IMPLAN provides deflator estimates through 2020. These deflators will be extrapolated to estimate deflators for later years.

The IOGCC publishes an annual report on the number of and production from marginal oil and gas wells. These reports, entitled *Marginal Wells*[11], focus on the availability and production of oil and gas resources from marginal wells[12] as well as the economic activity that arises from increasing production from these marginal wells. Two key differences between the IOGCC report and DOE's project *Valuing Domestically Produced Natural Gas and Oil* are: a) geographic breakdown and coverage and b) production process coverage.

In the IOGCC report, production and economic impacts are reported on a state-level basis for eleven states. The eleven states selected for the IOGCC study are those deemed to be the top oil producers in the country, excluding Alaska. These eleven states are responsible for more than 90 percent of marginal oil well production[13]. When marginal gas production was added to the IOGCC study, the eleven states selected based on oil production were maintained for consistency, even though these eleven states only have about 43 percent of the total marginal gas wells in the United States[14]. Further, the eleven states selected exclude the Appalachian states even though the Appalachian Basin accounts for about 51 percent of the marginal gas well count and almost 29 percent of the marginal gas produced[15].

In contrast all contiguous continental United States will be included in the research area for the DOE project – some are covered through single- or multi-state regions, while all are covered in the US-Lower 48 model region. This difference will allow for a more comprehensive coverage of both oil and gas production, though this is more notable for gas production. Additionally, in the DOE project, selected states will be grouped into five state or multi-state sub-national regions of particular interest.

The IOGCC report includes production and activity data for marginal wells. According to the latest IOGCC report these wells contributed 18 percent of oil and 9 percent of natural gas produced in this country in 2006[16]. The DOE report will provide a broader view of impacts from increased activity in the oil and natural gas industries by modeling impacts derived from increased domestic oil and natural gas production regardless of reserve type or production method.

The IPAA publishes an annual report[17] detailing domestic oil and natural gas production, cost, price, consumption and other economic data. The IPAA report provides these data on a state and national level. The primary distinctions between this project and the IPAA report are the goals of the projects and consequently, the reported data. The IPAA report provides point information on the number of wells, levels of production and reserves, unit costs for drilling wells and selling a barrel of oil or mcf of gas, average number of employees per related sector and so on. This

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[11] IOGCC. *Marginal Wells: 2007 Report*, August 2007. http://www.iogcc.state.ok.us/PDFS/2007-Marginal-Well-Report.pdf.
[12] Marginal oil wells are those producing 10 or fewer barrels of oil per day. Marginal gas wells are those producing 60 or fewer thousands of cubic feet of gas per day.
[13] IOGCC, 2007. p. 24.
[14] IOGCC, 2007. p. 25.
[15] IOGCC, 2007. p. 25.
[16] IOGCC, 2007. p. 6.
[17] IPAA, *The Oil and Gas Producing Industry in Your State*, July 2005. http://www.ipaa.org/reports/econreports/IPAAOPI.pdf

project, *Valuing Domestically Produced Natural Gas and Oil*, will use such data as guidance and calculation inputs for the valuation of domestic production that will be conjoined with a macroeconomic modeling framework. This approach will provide both point impacts and downstream impacts of increased production at both national and sub-national regional levels. Further, the IPAA report reflects industries' current production and market status while this project aims to estimate the incremental value of increasing domestic production as an offset to imports, thus capturing potential benefits from altering industries' current production.

As part of the modeling and results analysis process, the project team will, at a minimum, compare the inputs and model results from this project to those in the IOGCC and IPAA reports. Should time allow, the methodology and results of this project will also be compared and contrasted to other comparable studies.

Section 3.0 Model Evaluation and Selection

3.1 Model Review

A review of general modeling frameworks and several specific models ultimately led to the selection of the input-output (IO) model as the analysis framework for this project. In addition to the IO framework and models such as the Job and Economic Development Impact Model (or JEDI and JEDI II), the computable general equilibrium framework and existing models, such as the All-Modular Industry Growth Assessment Model (AMIGA) and National Energy Modeling System (NEMS) were also evaluated. Each of these frameworks and specific models were evaluated along a number of dimensions, including methodological basis, strengths, weaknesses, geographical scale, data requirements, model outputs, and representative applications. The following section presents a brief description of the input-output modeling framework to be used in this project. A general and comprehensive introduction to and description of the fundamental input-output model is included as an Appendix to this report.[18]

The description below extends that description to more accurately reflect the specific data that forms the input-output foundation of the analyses of this project.

3.2 The Input-Output Model and Accounting Framework

The foundation for an input-output model is an accounting framework that characterizes the purchases and sales of industries within an economy. Early input-output accounting frameworks divided the activities in an economy into industries, final demand activities and payment sectors. Final demand activities include consumption, investment, government expenditures, and net exports. Payments sectors are those activities to which industries make payments and include households, profits, indirect business taxes, and imports. Both final demands and payments sectors can be more finely disaggregated. One difficulty in characterizing purchase and sales

[18] The appendix and complete evaluation of alternative modeling frameworks can be found in NETL DOE/NETL-404.03.02/020408, Modeling Options for EPAct Project: Valuing Domestically Produced Natural Gas and Oil.

relationships for modeling purposes is that industries often produce more than a single commodity output. Most will produce a dominant commodity output along with some number of secondary commodity byproducts. In 1972, governments began to publish input-output accounting data in a commodity-by-industry format to provide a more comprehensive and accurate mechanism for modeling the relationships among industries and activities. This section presents an overview of this framework and of the computational algorithms that produce the kinds of impact analysis on which this project focuses.

The table below is a schematic diagram of the generalized commodity-by-industry accounting framework.

Table 1. Commodity-by-Industry Accounting Framework

	Commodities	***Industries***	***Final Demand***	***Total Output***
Commodities		U	E	q
Industries	V			g
Value Added		W		
Total Input	q’	g’		

Four tables define the information generally included in published data sources. These are U, V, E, and W. U is called the Use table (all of these tables are generally represented in matrix format, so are often referred to as matrices rather than tables) and represents the use of commodities by industries. The number of industries and commodities is not required to be equal, but in practice there is a one-to-one correspondence among them. Table V is called the Make table and represents the commodities produced by industries. The Use table is also called an absorption table, and the Make table is often called the byproducts table. The sum across any commodities row of U and E equals total commodity output. The sum down any industry's column of *U* and *W* equals total industry input. The sum across an industry row of the Make table equals total industry output, while the sum of any commodity column of the Make table equals total commodity output. By definition, total commodity or industry inputs equal total commodity or industry output. These identities are reflected mathematically in the first six equations below:

1) $Ui + E = q$
2) $Vi = g$
3) $V'i = q$
4) $B = U\hat{g}^{-1}$
5) $U = B\hat{g}$
6) $q = Bg + E$
7) $D = V\hat{q}^{-1} \rightarrow d_{ij} = v_{ij} / q_j$

B is a standardized version of the Use table that depicts dollars worth of commodity input per

dollar of industry output. Its use embodies the linear technology assumption and defines the input-output coefficients. Equation 7 reflects the industry-based technology assumption, which implies that an industries output product mix is variable, and that the total output of a commodity is produced by industries in fixed proportions. Hence, D is the standardized version of V that describes the commodity output distribution of industries.

The total commodity or industry requirements to satisfy a given level of commodity or industry final demand can be derived from these basic equations. For example, the total commodity requirements necessary to meet a given commodity final demand can be derived as:

8) $V = D\hat{q}$

9) $D\hat{q}\mathbf{i} = g$ (from 2)

10) $g = Dq$

11) $q = BDq + E$ (from 6)

12) $\left(I - BD\right)^{-1} E = q$

Likewise, total commodity requirements to meet a specified industry based final demand are derived as:

13) $Y = DE$

14) $E = D^{-1}Y$

15) $\left(I - BD\right)^{-1} D^{-1}Y = q$

Total industry requirements to meet a specified commodity final demand is shown in equation 17 and total industry requirements to meet industry based final demand is shown in equation 21, below.

16) $\left(I - BD\right)^{-1} E = D^{-1}g$

17) $D\left(I - BD\right)^{-1} E = g$

18) $E = (I - BD)D^{-1}$ (from 16)

19) $E = (D^{-1} - B)g$

20) $DE = \left(I - DB\right)g$

21) $\left(I - DB\right)^{-1} Y = g$ (from 13: $Y = DE$)

The formats in which the data are published therefore provide a great deal of flexibility in modeling choices. The expression most compatible with and supportive of the analysis for this project is the industry by commodity relationship represented in equation 17. Our base model will provide commodity final demand and the Use and Make tables that will be edited as described in Section 6.2 on the table editing procedures for the model.

Section 4.0 Definitions of Regions Used in the Model

The analysis conducted through this project will explore the potential impacts of domestic natural gas and oil production on a regional and national basis. Therefore, a key decision point in this project was the definition of analytical regions. The project models six United States regions – five sub-national regions and one national region. The nation as a whole is modeled separately because there are interregional interactions that are not captured when modeling impacts within one region. Therefore, the sum of the impacts over the five sub-national regions will not correspond to the sum of the impacts on the nation. The difference between the national impacts estimate and the sum of the region-specific impacts is attributable to interregional economic interaction.

The results of this analysis will, at a minimum, include incremental impacts of producing natural gas and oil domestically on gross output, jobs and taxes. Current data on these economic factors are generally reported on a state-level basis. Additionally, natural gas and oil supply and demand data are also on a state-level basis. As such, it was important to define the analytical regions along state lines.

Because the primary focus of this analysis are the impacts associated with increased domestic natural gas and oil production, the regions, in addition to following state lines, also needed to represent states with large reservoirs and production levels. The primary resource used to guide the construction of the regions was the "Major Oil and Natural Gas Basins of the United States" map[19] that is based on data from the Energy Information Administration (EIA). Additionally, resource areas that are the focus of EPAct 999-directed research were also considered in the development of the final regions. To the greatest extent possible, large resource reservoirs that cross state lines were kept within the same region, although this was not always possible. States with little or no natural gas or oil production were not included in any of the sub-national regions and will only be included in the national level analysis.

[19] The "Major Oil and Natural Gas Basins of the United States" map is Figure 9 in the Design Basis Document.

The final regional delineation is shown in the region-level maps below.

Figure 2: Region 1. Marcellus Shale (New York, Pennsylvania, Ohio, West Virginia)

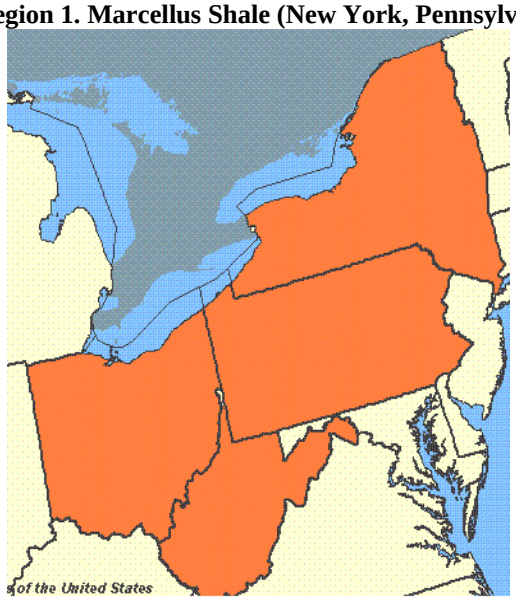


Figure 3: Region 2. Bakken Shale (Montana, North Dakota)

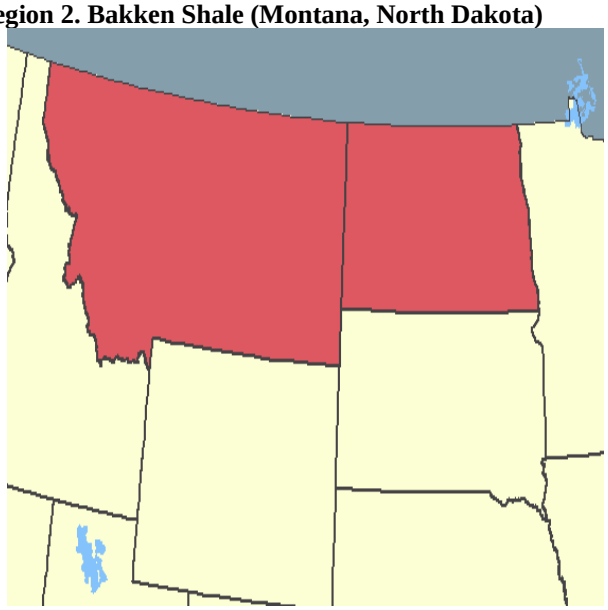


Figure 4: Region 3. Barnett Shale (Texas)

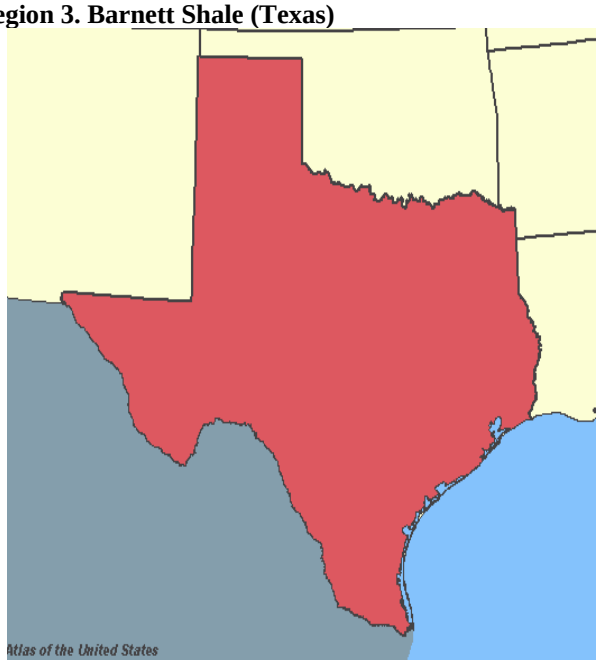


Figure 5: Region 4. Greater Green River/Pinedale Anticline/Jonah Field (Colorado, Utah, Wyoming)

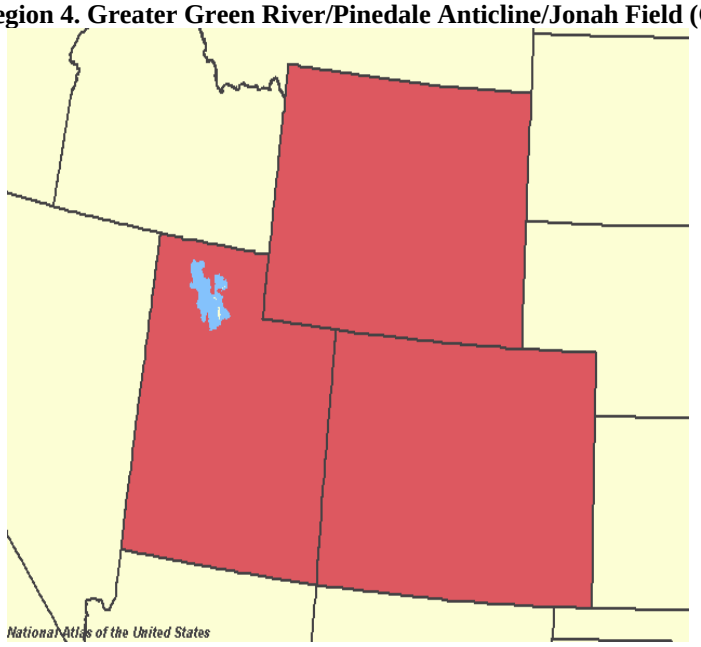
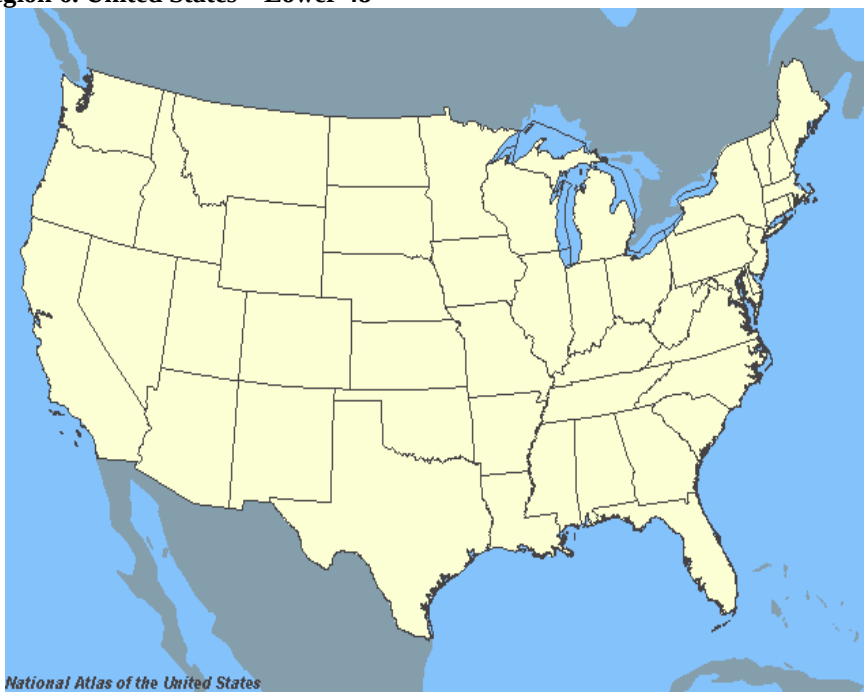


Figure 6: Region 5. California (California)

Figure 7: Region 6. United States – Lower 48



Section 5.0 Model Data Sources

As noted in Section 1.0, this project will analyze potential impacts from increased domestic natural gas and oil production using the IMPLAN input-output database. This project uses the latest version of IMPLAN, which is for 2006. More information on the IMPLAN model and its use in this project is provided in Section 6.0.

To assess potential impacts from increased domestic natural gas and oil production it is imperative to understand the regions' current activities related to demand, production, supply, prices, and employment as well as the natural gas and oil industry's inter-industry relationships. Because it provides the majority of natural gas and oil market data (demand, production, supply and prices), the EIA is the primary data source for this project. Annual 2006[20] data were collected and aggregated to the regional level for inclusion in the model. Import and export data were arranged to identify the volumes of interregional and international flows and average trade prices were calculated by aggregating and averaging state-level data as shown in Table 2.

Table 2. Example of International Trade Price Calculations

Region	*State*	*Import Volume (Natural Gas, MMcf/yr)*	*Import Price ($/tcf)*	*Value of Imported Natural Gas (volume x price) (thousand $)*	*Regional Average Import Price ($/tcf)*
2	Montana	684,279	$6.75	$ 4,616,768	Calculated as regional value divided by regional volumes
2	North Dakota	514,053	$6.71	$ 3,451,307	
2		**1,198,332**		**$ 8,068,074**	**$6.73**

Market prices for processing plant byproduct output were drawn from Barnes & Click, Inc and margin ratios for converting producer and purchaser prices were extracted from the Bureau of Economic Analysis' (BEA) 2002 Benchmark Input-Output Tables.

The boundaries for this study, as noted in Section 1.2, extend from the field to the back end of the processing plant for natural gas that requires processing and to the gathering center for natural gas not requiring processing as well as for crude oil. Once production increases, impacts on field level activity and the industry's supporting infrastructure will be calculated. These calculations, more thoroughly discussed in Section 7.1, are based on data such as per well production levels, processing plant capacity and utilization rates, oil pipeline capacity and utilization rates and construction data for wells, processing plants and pipelines. As with the market data, the EIA serves as the primary data source for production rates, well counts and plant and pipeline capacities and utilization rates.

[20] 2006 data were used because these are consistent with the data in the model's framework data from IMPLAN and because 2006 is the most current complete year available for nearly all required data sets required for this study.

Construction data for natural gas and oil wells are derived from the 2003 Joint Association Survey on Drilling Costs (JAS). These costs are provided by state and by well depth. In input-output accounts, such as those provided by BEA, well construction is part of fixed investment. Following BEA's approach of using the Producer Price Index (PPI) do deflate costs associated with well construction, the 2003 drilling costs provided by the JAS were inflated to 2006 costs using the PPI for industry 213111 (Drilling Oil and Gas Wells), product 213111213111 (Drilling Oil and Gas Wells).

Gathering pipeline costs are based on onshore data provided in the O&G Journal's 2007 U.S. Pipeline Costs Survey. These data (capital cost/well) are combined with data on existing gathering pipeline mileage[21,22], EIA data on onshore wells and production and an estimate for the percent of existing lines that are useful (set at 80% for calculation purposes).

State-level data on processing plant construction costs are derived from cost data in Kidnay and Parrish, *Fundamentals of Natural Gas Processing*, 2006, EIA's *U.S Crude Oil, Natural Gas, and Natural Gas Liquids Reserves Report* and USGS's *2006 Mineral Yearbook (Sulfur).*

Section 6.0 Regional and National Table Construction Methodology

6.1 Input-Output Model Obtained from IMPLAN

Software and data purchased from the Minnesota IMPLAN Group, Inc. forms the foundation for the regional input-output models and for the national input-output model. All of the models have been constructed with the IMPLAN software, using 2006 structural and region-specific data.

Within each model, trade flows, the transfer of goods and services between the region and the rest of the world are estimated using the average regional purchase coefficient (RPC) method. The RPC method estimates trade flows based on econometric equations internal to IMPLAN. These equations are based upon a number of regional-to-national variables, including the wage ratio, 'other costs' ratios, output ratios, the commodity weight/value ratio, the ratio of the number of users of a good, the ratio of the number of producers of a good, and the land area ratio.
The baseline and impacts estimates of relevant variables will be generated using the independent modeling framework developed in this project. The following data are extracted from IMPLAN and saved in spreadsheet form for use in the impacts assessment model:

- Regional Use Table – contains the information on the use of commodities by industry: the dollar value of purchases of goods and services by each industry for use in the production process
- Regional Make Table – contains the information on the output distribution of commodities by industry: the dollar value of each good and service produced by each industry

[21] Natural Gas: http://www.naturalgas.org/naturalgas/processing_ng.asp & Pipeline and Hazardous Materials Safety Administration, US DOT http://ops.dot.gov/stats/stats.htm
[22] Oil: http://www.pipeline101.com/Overview/crude-pl.html

- Total Commodity Imports – sum of intermediate and institutional imports of commodities (goods and services)
- Total Commodity Final Demand –institutional demand for the final use of commodities: includes the household consumption portion of final demand
- Employment by Industry – total employment (number of jobs) for each industry (sector)
- Tax Multipliers – multipliers for all tax variables, including business taxes, expressed in dollars by type per dollar of industry output

6.2 Table Editing Procedure

The Input-Output (IO) modeling framework forms the analytical basis for this project. However, unlike most conventional final demand driven IO applications, this project focuses on the changes that can be expected to occur in response to increased domestic (intraregional) production replacing previously imported oil and gas (commonly referred to as *import substitution*). Whereas the former analyses are implemented by driving an existing structural model with a new final demand or final demand change vector, the latter are implemented by driving a model based on an edited IO structure by unchanged final demand. Our analytical model will accommodate both modes of analysis, along with combinations of modes when called for. Import substitution impacts will be computed as differences in model outputs between the initial baseline outputs and those of the edited model.

There are two general categories of impacts our model will assess. These are the impacts of increased domestic production and the impacts of any new construction necessitated by the shift from imports to domestic production. Whereas construction impacts are associated with one-time events, production impacts are considered to be long run and annually recurring. Hence, the two impacts categories are reported separately. The modeling approach for each of these impacts categories will be addressed separately, below.

6.2.1 Import Substitution Impacts

As domestic production increases, the first and most direct impact will be on the output-increasing industry (or industries). This output increase results in greater numbers of employees and their associated income in the producing industry (and region), and it results in increased demand for intermediate materials and supplies used in the industry's production process. A second impact will be reflected in larger dollar transactions associated with sales from the output-increasing industry to any other domestic sectors that previously had to import the supplies now available from domestic sources. The latter changes also imply potential changes in transport costs (margins), particularly when transportation distances have changed markedly. However, margins also were associated with the previous import purchases. Hence, there may in fact be no detectible change in the margins associated with import substitution. Were cases to arise in which there is high confidence that margins associated with domestic production are substantially different from those associated with imports, and in instances where these differences were quantified with high levels of certainty, the table could be edited to reflect the new margin values. To date, however, no such instances have been identified. Therefore, this mechanism is not included in the prototype model and not expected to be a feature of the final model.

Sub-national regional IO models differ most markedly from national IO models in their greater reliance on imports because sub-national regions are typically more open to trade than their national counterparts. This is reflected in the values in supplying rows of the regional IO coefficients table being less than (or at most equal to) their national counterpart values, such that the regional trade coefficient plus the imports coefficient equals the corresponding national coefficient. Table editing for import substitution therefore proceeds by effectively increasing the (intra)regional coefficients in the output-increasing row in proportion to the increases in domestic supply. These regional trade coefficient increases will continue until the point at which they equal their national counterpart values. At this point, all domestic (intraregional) demand for the industry's output will have been satisfied. Any additional output over and above the intraregional demand will be added to the baseline final demand vector in the appropriate industry row. The appropriately adjusted baseline final demand vector will then be used to drive the newly edited model.

In actual implementation, table editing takes place in a byproducts matrix. Modern input-output accounts are published in what is known as commodity by industry format; this is also the format of the IMPLAN data that forms the basis of our analyses. Rather than the more traditional inter-industry input-output tables, the foundations of the commodity by industry accounts are the Use and Make tables. The Use table is organized as a series of columns, one per industry, with each row corresponding to a commodity used as an input to the column industry's production process. Commodities and industries generally share common names, with the industry being named according to its primary commodity output. This table, populated by the dollar value of commodities used by each industry, represents the technical requirements of each industry for the production of its output over the course of a one year period. When the columns of the Use table are standardized by corresponding industry output values, the values in each cell of the table can be interpreted as cost shares, and can be referred to as input-output technical coefficients.

The Make table is also referred to as a byproducts table. The rows of this table refer to industries, while the columns refer to commodities. The dollar values along any row represent the primary and secondary commodities produced by the row industry. In addition to the regional industries represented as rows in a byproducts table, there will be a final row that refers to a rest-of-world industry, which is the source of commodity imports. Because this row is present, the sum of the values in any commodity column will be equal to the total supply of the commodity available for the satisfaction of regional and export demand. As an industry increases domestic (regional) production and reduces its imports of a commodity, the element in that industry's row for the commodity whose output is being increased will take on a larger value, and the rest-of-world industry value for that commodity will be decreased. When used to generate an inter-industry table, the mathematical operations will have the effect of increasing intraregional cost shares for the strengthening domestic industry and decreasing import cost shares – which is the goal of modeling import substitution.

Should the commodity output increase exceed the amount of commodity formerly imported for satisfying regional demand, the excess will be added to the baseline final

demand vector. The edited IO matrix will be post-multiplied by the final demand vector to generate a counterfactual activity level, which will be compared to the baseline activity level to estimate the impacts of the import substitution. Activity levels will include industry output, employment, income, and tax revenues.

A final consideration in the substitution of domestic production for imports concerns the characteristics of the domestically sourced natural gas. Imported natural gas is considered "clean". Domestically produced gas requires an additional processing step to separate byproduct gases in the cleaning process. This results in a moderate shift in the distribution of outputs of the gas processing sector away from the dominant output and toward the byproducts. This shift can be reflected in an edited Make table to the extent that this shift can be quantified.

6.2.2 Construction Impacts

Because the input-output model is a current accounts modeling framework, the investment in construction of new production facilities should not be included in a model intended to identify ongoing, annually recurring impacts. The impacts of these investments, however, can be captured separately. These impacts will occur once, but not continue in subsequent years. To model these construction impacts, total construction dollar investments are translated into final demands for goods and services necessary for the particular kinds of production facilities involved. For this model, we are interested in the construction impacts associated with natural gas and oil wells. Final demand vectors constructed in this way drive the input-output model computation in the conventional fashion.

While there will be new operating and maintenance expenditures associated with the operation of the new natural gas and oil wells, they are already effectively captured by increased output values that result from the increases in intraregional inter-industry interaction. They are implicitly embedded in the input-output structure for the region and need not be handled separately.

6.3 International Trade Feedback Effects

As US imports of oil and gas are offset by increased domestic production, countries that formerly exported to the US will either export to other countries or will simply export less. In the latter case, the loss of income to such countries could result in decreased imports of US goods. The maximum decrease in their imports from the US would correspond to a US export decline equal to the value of the formerly imported oil and gas. The maximum possible impact is unlikely, since those countries would be expected to find other markets for some portion of the oil and gas formerly sold to the US, and since some portion of the declines in their imports would be expected to impact countries other than the US. Even with detailed historical trade data, the proportion of the displaced **import** value not received and hence not re-spent by foreign countries on US goods would be virtually impossible to predict with accuracy. Hence, the model allows for this proportion to be specified by the user, with values ranging from zero to a

maximum of 20% of the value of displaced imports. Let P^X denote this "feedback" proportion, whose default value will be set at 0.2.

The value of the reduction in US exports will equal the product of the feedback proportion and the value of displaced imports. We assume that the reduction in national exports of each commodity will be proportionate to each commodity's share of total base year national exports. The region's share of the reduction in foreign exports for a given commodity will be proportionate to the region's share of national exports of that commodity. If we let Δ denote *change in*, X_i^r denote region r commodity i exports, X_i be commodity i national exports, and X be total national exports, then

$$\Delta X_i^r = \left(P^X\right)\left(IS_i\right)\left(\frac{X_i^r}{X_i}\right)\left(\frac{X_i}{X}\right) = \left(P^X\right)\left(IS_i\right)\left(\frac{X_i^r}{X}\right)$$

where IS_i is the value of displaced imports. Changes in exports are then subtracted from the baseline final demand vector to generate the impact final demand vector in non-oil & gas commodity sectors.

Section 7.0 Spreadsheet Model Construction

The model used to assess the impacts of increased natural gas and oil production is an Excel spreadsheet model. The model is comprised of a region map sheet, a user-interface sheet, a results sheet and multiple data and calculation sheets. All data, unless otherwise noted, are for calendar year 2006. Natural gas is presented in million cubic feet per year (MMcf/yr) and oil is presented in thousand barrels per year (kbbls/yr), unless otherwise noted.

The user interface, tab "Inputs" allows the user to select the region for analysis and enter the volumes of increased wellhead production and the well depth for the region. As the user makes selections on well depth, the model presents the per-well drilling costs for that region (thousand $/well). Also presented to the user are the producer prices for natural gas and oil. Lastly, this portion of the model presents the user the option to set an international trade feedback rate. This percentage, bound to 0% to 20% reflects the impacts of increased regional production that leads to a decline in international natural gas and/or oil import. These reduced imports could cause a decline in revenue by the exporting country. The decline in international revenue could then cause a downstream decline in imports of US goods by impacted countries.

Below the user input section of this tab, data on the current (2006) state of activity within the region are presented to the user as guidance for the user's selection of increased regional production. The data presented as informational guidance and the calculations used to convert user production inputs into model inputs (converting production volumes into dollars) are based on data held in the tabs "NG Data Sheet" and "Oil Data Sheet". The following section details how the informational values and the model input values are calculated; more information on the base data in tabs "NG Data Sheet" and "Oil Data Sheet" will be explained in more detail later in this section. Detailed instructions for this tab are in the section *User Instructions*.

7.1 Calculations

7.1.1 Regional Information

The box "Regional Information" on the tab "Inputs" provides the user with information on the current industry-related activities within the region. These data are provided to inform the user's entries for increased production based on the region's current supply and demand balance.

a. Regional Demand: $\sum_{S1}^{Sx} C$ where C=consumption in all sectors, S=state within region

b. Regional Imports: $\sum_{R1}^{R5} M$ where M=imports from all other regions and international sources, R=exporting region. Imports between states in the same region are considered regional production and are not counted as regional imports.

c. Current Well Withdrawals:

Natural Gas: $\sum_{S1}^{Sx} NGPng, o$ where NGP=wet production of natural gas, ng = gas wells, o = oil wells, S=state within region

Crude Oil: $\sum_{S1}^{Sx} OPng, o$ where OP = crude production of oil, ng = gas wells, o = oil wells, S=state within region

d. Number of Wells: $\sum_{S1}^{Sx} W$ where W=fuel specific producing wells, S=state within region

e. Current Marketed Production (applies only to natural gas): $\sum_{S1}^{Sx} Pg - PLg$ where Pg=wet production of natural gas from gas and oil wells, PLg=production losses from re-pressuring, venting/flaring and removal of non-hydrocarbon gases, S=state within region

f. Natural Gas Processing Plant Capacity: $\sum_{S1}^{Sx} \left(\sum_{Plant1}^{Plantx} NGC * 365 \right)$ where NGC=natural gas processing capacity per day, Plant=processing plant facility, S=state within region

g. Average Utilization Rate:

$$\left(\sum_{S1}^{Sx}\left(NG\Pr ocessed\right)\right) \Big/ NaturalGas\Pr oces\sin gPlantCapacity$$

h. Current Dry Production (applies only to natural gas): $\sum_{S1}^{Sx} Pg - PLg - NGLg$

where Pg=wet production of natural gas from gas and oil wells, PLg=production losses from re-pressuring, venting/flaring and removal of non-hydrocarbon gases, NGLg= natural gas liquid constituents such as ethane, propane, and butane removed at natural gas processing plants S=state within region

i. Average Natural Gas Processing Plant Capacity: $\sum_{S1}^{Sx}\left(\sum_{Plant1}^{Plantx} NGC * 365\right) \Big/ \sum_{S1}^{Sx}\left(Plants\right)$

7.1.2 Production Results

Input values for input-output based models must be in dollar format and in producer's prices. Therefore the production level values entered by a user must be converted to producer's price dollars to drive the impacts assessment model. Calculations shown in Sections 7.1.2 through 7.1.4 provide a walk-through of the calculations used to do this production-to-value conversion.

As noted in Section 1.3, the scope of this project includes natural gas processing. This allows the impacts to encompass the production of natural gas liquids that are produced when wet natural gas is cleaned to pipeline quality levels. Prior to the production-to-value conversion occurs, the volume of additional natural gas produced at the wellhead must be converted to the volume of natural gas that reaches the processing plant market (marketed production). This volume must then be stripped of natural gas liquids, leaving the volume of natural gas that will enter the transmission and distribution system (dry natural gas).

a. Increased Marketed Production (natural gas): Increased market production is defined as the gross withdrawals of natural gas less gas used for re-pressuring, quantities vented and flared, and non-hydrocarbon gases removed in treating or processing operations[23]. The Energy Information Administration (EIA) provides state-level data on gross withdrawals and process losses. These data were aggregated into the model regions and the regional process losses percentage, the parameter directly used by the model, was calculated as a percent loss of regional wet production volumes.

[23] EIA Glossary, Marketed Production, http://www.eia.doe.gov/glossary/glossary_m.htm.

$$\text{Source Data Process Losses}_R = \sum_{S1}^{Sx} \text{Pr}\,ocessLosses$$

$$\text{Source Data Marketed Production}_R =$$

$$\sum_{S1}^{Sx} \text{Current We ll Withdrawa ls - Process Losses}$$

$$\text{Source Data Regional Process Loss Percent} =$$

$$\text{Pr}\,ocessLosse\ s_R \Big/ Marketed\ \text{Pr}\,oduction_R$$

In the model, increased marketed production from increased regional natural gas production is calculated as:

Increased Marketed Production = Increased Regional Production_{NG} * (1- Regional Process Loss Percent)

b. Natural Gas Sent to Processing: According to EIA data, 23.5 Tcf[24] of wet natural gas was produced in the United States in 2006. This production yielded 19.4 Tcf[19] of marketed production of which 14.7 Tcf[25] (76%) was sent to natural gas processing plants for further processing. These data were also available on a state level and were used to calculate the regional volumes of marketed production that were and were not sent to natural gas processing plants.

$$\text{Source Data Processed Volumes}_R = \sum_{S1}^{Sx} \text{Pr}\,ocessedVolumes$$

NG Not Requiring Processing_R = Increased Marketed Production * (1-(Source Data Processed Volumes_R ÷ Source Data Marketed Production_R))

Processed NG_R = Increased Marketed Production * (Source Data Processed Volumes_R ÷ Source Data Marketed Production_R)

[24] EIA. Natural Gas Gross Withdrawals and Production. http://tonto.eia.doe.gov/dnav/ng/ng_prod_sum_dcu_NUS_a.htm

[25] *U.S Crude Oil, Natural Gas, and Natural Gas Liquids Reserves Report*. Appendix E, Table E4. Natural Gas Processed and Liquids Extracted at Natural Gas Processing Plants, 2006

c. Natural Gas Processing Plant Output: Once the volume of natural gas that is sent to processing is determined (by calculation Processed NG_R), the volumes of extraction losses[26], extracted liquids and dry natural gas[27] output must be calculated. EIA presents state-level data on the volume of natural gas processed (MMcf), the total liquids extracted (kbbls) and the extraction loss (MMcf) of natural gas[28]. The relationship between these data is used to calculate the losses, liquids and dry natural gas from the increased natural gas sent through a processing plant.

Extraction $Loss_R$ = Processed NG_R * (Source Data Extraction $Loss_R$ ÷ Source Data Processed $Volumes_R$)

where Source Data Extraction $Loss_R$ = $\sum_{S1}^{Sx} ExtractionLosses$

Extracted $Liquids_R$ = Extraction $Loss_R$ * Percent Liquids-to-Extracted $Liquids_R$

where Percent Liquids-to-Extracted $Liquids_R$ = Source Data Extracted $Liquids_R$ ÷ Source Data Extraction $Loss_R$)

where Source Data Extracted $Liquids_R$ = $\sum_{S1}^{Sx} ExtractionLiquds$

Dry Natural Gas from Processing $Plants_R$ = Processed NG_R - Extraction $Loss_R$

d. Total Dry Natural Gas to Market: The amount of dry natural gas that is sent to the natural gas transmission and distribution market represents both the volumes that did not require additional processing and the dry natural gas output by the processing plant industry.

Total Dry Natural Gas to $Market_R$ = NG Not Requiring $Processing_R$ + Dry Natural Gas from Processing $Plants_R$

[26] Extraction losses are the reduction in volume of natural gas due to the removal of natural gas liquid constituents such as ethane, propane, and butane at natural gas processing plants. http://tonto.eia.doe.gov/dnav/ng/TblDefs/ng_prod_sum_tbldef2.asp

[27] Dry natural gas is consumer-grade natural gas and is the natural gas which remains after the liquefiable hydrocarbon portion has been removed from the gas stream (i.e., gas after lease, field, and/or plant separation) and any volumes of non-hydrocarbon gases have been removed where they occur in sufficient quantity to render the gas unmarketable. EIA Glossary, Marketed Production, http://www.eia.doe.gov/glossary/glossary_d.htm.

[28] EIA, Natural Gas Processing. http://tonto.eia.doe.gov/dnav/ng/ng_prod_pp_dcu_nus_a.htm

e. Crude Oil Production: As previously noted, the boundary of this project, with respect to crude oil production, ends at the gathering line that then sends crude oil to the refinery. Therefore, the only reported production volume reported for crude oil is the increase in crude oil production without any processes having taken place.

$$\text{Crude Oil Production}_R = \text{Increased Regional Production}_O$$

7.1.3. Impact on Supply Allocation

Once the conversion of increased wellhead production to increased marketed production is complete, the role of this increased production must be determined.

a. Allocation of Increased Production to Regional Demand: A key assumption to this portion of the model is that total regional demand is constant. Given constant demand, increases in production either meet current demand, thus offsetting current imports, or increase regional exports. The allocation of increased production to current demand or increased exports is determined by the regions ability to meet demand given baseline (current) production. Therefore, if regional demand exceeds baseline dry production (natural gas) or well withdrawals (crude oil), then increased production goes toward meeting regional demand up to the point that regional demand is satisfied. The volume applied to regional demand offsets regional imports while any excess production volumes are exported (see example 1).

Example 1: Region Demand (D) = 500,000 MMcf/yr
Region Production (P) = 375,000 MMcf/yr
Region Production Variance = 500,000
- 375,000
= 125,000 MMcf/yr

Increased Regional Production set at 300,000 MMcf/yr
Increased Production to Regional Demand
= Region Production Variance
= Offset Imports
= 125,000 MMcf/yr

Increased Production Exported = 300,000
- 125,000
= 175,000 MMcf/yr

If baseline production levels already satisfy the regional demand, then any increase in regional production is exported (see example 2).

Example 2: Region Demand (D) = 300 kbbl/yr
Region Production (P) = 475 kbbl/yr
Region Production Variance = 300
- 475
= -175 kbbl/yr

Increased Production Exported = 175 kbbl/yr

b. Determining Inter-regional and International Shares of Offset Imports and Increased Exports: Each sub-national model region is supplied by regional and/or imported natural gas and oil[29]. Additionally, each sub-national region exports natural gas and oil to other sub-national regions and to international markets. When increased domestic production meets the regional demand, thus offsetting imports, it must be determined whether these offset imports are imported from other sub-national US regions or if they are international imports. Additionally, when increased production within a region exceeds the region's demand, as in example 1 above, or when the increased production is not needed within the region, as in example 2, the excess supply will be exported and it must be determined whether these exports will supply other sub-national US regions or will enter the international markets. The split between sub-national and international markets for both offset imports and increased exports is determined by the aggregation of state-level proportions as reported by the EIA.

Example 3. From Example 1, offset imports = 125,000 MMcf/yr and EIA data show that in 2006 Region X imported 775,000 MMcf/yr from other sub-national regions and 1,120,000 MMcf/yr from the international market, for total imports of 1,895,000 MMcf/yr.
Region X regional imports = 775,000/ 1,895,000 = 41%
Region X international imports = 1,120,000/1,895,000 = 59%

Given these data points, the model will calculate:
Offset imports (US Regions) = 51,121 MMcf/yr (125,000*41%)
Offset imports (International) = 73,879 MMcf/yr (125,000*59%)

[29] For the United States-Lower 48 region, all imports and exports are sourced from and sent to the international market with no allocations to sub-national regions.

Example 4. From Example 2, increased exports = 175 kbbl/yr and EIA data show that in 2006 Region X exported 250 kbbl/yr to other sub-national regions and 75 kbbl/yr to international markets, for a total exported volume of 325 kbbl/yr.

Region X regional exports = 250/325 = 77%
Region X international exports = 75/325 = 23%

Given these data points, the model will calculate:
Increased exports (US Regions) = 135 kbbl/yr (175*77%)
Increased exports (International) = 40 kbbl/yr (175*23%)

7.1.4 Calculating Increased Regional Industry Output & Reduced Import Payments

The calculations shown in steps 7.1.2 and 7.1.3 move the production volumes from raw production to volumes that will enter the transmission and distribution system (natural gas) or be sent to a refinery (crude oil). The final step needed before executing the model is to convert the production volumes meeting demand and/or being exported into industry output valued in producer prices (million $). Additionally, the value of offset imports must be captured by converting offset import volumes to offset import payments.

a. Natural Gas Industry Output: Output for the natural gas industry is comprised of three components – natural gas sold for regional consumption, natural gas exports and sales of natural gas liquids.

NG Regional Demand (Million $) = Total Dry Natural Gas to Market_R (MMcf/yr) * (Imputed Wellhead Price_R ($/mcf)[30,31]) ÷ 1,000

NG Regional Exports (Million $) = [(Increased exports (United States Regions) + Increased exports (International)] * (Imputed Wellhead Price_R ($/mcf)) ÷ 1,000]

NG Plant Liquids (Million $) = Extracted Liquids_R (kbbls/yr)* Avg NGPL Market Value_R($/bbl)[32] * Avg Industry Ratio of Producer's Prices to Purchaser's Prices (%)[33] ÷ 1,000

[30] EIA. Natural Gas Prices, wellhead price. http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_a_EPG0_FWA_DMcf_a.htm
[31] No adjustment is made to wellhead prices – assumed to be producer prices.
[32] Regional average NGPL production: EIA, Natural Gas Plant Field Production, state-level data; NGPL prices: Barnes and Click: http://www.engineers1.com/pdf/PriceCorr.pdf
[33] Bureau of Economic Analysis (BEA), Benchmark Input-Output Data, Table 2. The Use of Commodities by Industries before Redefinitions, 2002 Benchmark, at the detail level. Average United States Purchaser-to-Producer ratio for purchases of NAICS 211000 (Oil & Natural Gas Extraction) by chemical industries NAICS 324191 (Petroleum Lubricating Oil and Grease Manufacturing), 324199 (All Other Petroleum and Coal Products Manufacturing), 325110 (Petrochemical Manufacturing) and 325190 (Other Basic Organic Chemical Manufacturing).

b. Reduction in NG Import Payments: This value represents the value of a region's reduced payments for natural gas imports from other sub-national regions and the international market.

Reduced NG Import Payments$_1$ (Million \$) =
$\sum_{R1}^{R6}(Offset\ \mathrm{Im}\ ports(MMcf\ /\ yr) * \mathrm{Im}\ putedWellhead\ \mathrm{Pr}\ ice(\$\ /\ mcf))$* Avg Industry Ratio of Purchaser's Prices to Producer's Prices (%)[34,35] ÷ 1,000

Reduced NG Import Payments$_2$ (Million \$) = Offset imports (International) * Avg Natural Gas Import Price$_R$ (\$/mcf)[36] ÷ 1,000

c. Oil Industry Output: Output for the oil industry is comprised of two components – oil sold for regional consumption and natural gas exports.

Oil Regional Demand (Million \$) = Crude Oil Production$_R$ (kbbl/yr) * Domestic Price to Refiners$_R$ (\$/bbl)[37] * Avg Industry Ratio of Producer's Prices to Purchaser's Prices (%)[38] ÷ 1,000

Oil Regional Exports (Million \$) =

i. Increased exports (US Regions) * Domestic Price to Refiners$_R$ (\$/bbl) * Avg Industry Ratio of Producer's Prices to Purchaser's Prices (%) ÷ 1,000 +
ii. Increased exports (International) * F.O.B Costs of Imported Crude Oil$_{US}$ (\$/bbl)[39] ÷ 1,000

[34] BEA, Benchmark Input-Output Data, Table 2. Average US Producer-to-Purchaser ratio for purchases of NAICS 211000 (Oil & Natural Gas Extraction) by NAICS 211000 (Oil & Natural Gas Extraction).
[35] Import payments must be in purchaser prices, so wellhead prices had to be increased to account transportation margins (largely pipeline transportation costs).
[36] EIA, United States Natural Gas Imports by Point of Entry, Pipeline Prices and LNG Prices
[37] EIA. Refiner Acquisition Cost of Crude Oil, domestic. http://tonto.eia.doe.gov/dnav/pet/pet_pri_rac2_a_EPC0_PDT_dpbbl_a.htm
[38] BEA, Benchmark Input-Output Data, Table 2. Average US Purchaser-to-Producer ratio for purchases of NAICS 211000 (Oil & Natural Gas Extraction) by NAICS 324110 (Petroleum Refineries).
[39] EIA, F.O.B Costs of Imported Crude Oil by Area, http://tonto.eia.doe.gov/dnav/pet/pet_pri_imc1_k_a.htm.

d. Reduction in Oil Import Payments: This value represents the value of a region's reduced payments for oil imports from other sub-national regions and the international market. The calculations are done similarly to the reduced natural gas import payment calculations.

Reduced Oil Import Payments$_1$ (Million \$) =

$$\sum_{R1}^{R6}\left(Offset\ \text{Im}\ ports(kbbl/yr) * \text{Domestic Price to Refiners}_R\ (\$/\text{bbl})\right) \div 1{,}000$$

Reduced Oil Import Payments$_2$ (Million \$) = Offset imports (International) (kbbl/yr) * Landed Cost of Imported Crude Oil$_{US}$ (\$/bbl)[40] ÷ 1,000

7.1.5 Construction Cost Results

a. Number of New Wells: Increased domestic production will lead to the construction of new wells given the assumption that none of the new production is due to increased recovery rates from existing wells. Additionally, although each region obtains both natural gas and oil from the wells within the region, the model calculates the number of new wells needed using the assumption that only natural gas wells will produce natural gas and only oil wells will produce oil.

New Natural Gas Wells (#) =

$$\text{Increased Regional Production}_{NG} \Big/ \left(\sum_{S1}^{Sx} GasWithdrawals \Big/ \sum_{S1}^{Sx} GasWells \right)$$

New Oil Wells (#) =

$$\text{Increased Regional Production}_{O} \Big/ \left(\frac{\sum_{S1}^{Sx} OilWithdrawals}{1{,}000} \Big/ \sum_{S1}^{Sx} OilWells \right)$$ [41]

[40] EIA, Landed Costs of Imported Crude by Area. http://tonto.eia.doe.gov/dnav/pet/pet_move_land1_k_a.htm

[41] Oil well withdrawals are divided by 1,000 because regional withdrawals in the source data are in thousand bbls/yr while increased regional production held in the model are in million bbls/yr.

b. New Well Construction: Total construction costs for new natural gas and oil wells are derived by multiplying the number of new wells required by the average regional construction costs per well plus any cost adjustment entered by the user.

Well Construction $Costs_R$ (Million $) = (New Natural Gas Wells (#), New Oil Wells (#)) * Avg By-depth Well Construction $Cost_R$ (thousand $/well) ÷ 1,000

c. New Gas Processing Plants (#): In 2006, there were 491 natural gas processing plants across 22 states[42]. These processing plants had a reported daily processing capacity that was extrapolated to an annual processing capacity for use in the model[43]. State-level processed volumes were used along with the capacity data to generate regional plant utilization rates and maximum regional utilization rates. The number of new processing plants required in each model region is a function of the region's processing plant maximum utilization rate, the new volume of natural gas requiring processing [see function Processed NG_R (step 7.1.2.b. shown above)] and the displaced processed inter-regional imports. The calculation for the number of new natural gas processing plants is a two step process that first compares the excess regional processing capacity an the volume of inter-regional natural gas that is processed within the region to the new volume of natural gas and then, if the new volume exceeds the displaced imports or the excess regional capacity, determines the number of new plants required within the region.

i. New Natural Gas Processing Plants Required (yes/no):
If Processed $NG_R \leq$ Source Data Inter-Region Processed Import $Volumes_R$
OR Processed $NG_R \leq$ Excess Processing Capacity,
Then no new plants are required; Else

ii. New Natural Gas Processing $Plants_R$ (#) =
If Processed $NG_R >$ Source Data Inter-Region Processed Import $Volumes_R$
Then

$$\frac{\left(\mathrm{Pr}\,ocessedNG_R - SourceDataInter\,\mathrm{Re}\,gional\,\mathrm{Pr}\,ocessed\,\mathrm{Im}\,ports_R\right)}{\left(\frac{MaxUtilizationVolume_R}{Plants_R}\right)}$$

Else $$\frac{\left(\mathrm{Pr}\,ocessedNG_R\right)}{\left(\frac{MaxUtilizationVolume_R}{Plants_R}\right)}$$

[42] *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves Report*. Appendix E, Table E5. Form EIA-64A 2006 Plant Frame Activity .

[43] *Natural Gas Processing: The Crucial Link Between Natural Gas Production and Its Transportation to Market*, Table 1. Natural Gas Processing Plant Capacity in the Lower 48 States, 1995 and 2004. These data were extrapolated to 2006 based on the capacity-to-plant ratio in 2004.

d. New Gas Processing Plant Construction: Total construction costs for new natural gas processing plants are derived by multiplying the net volume of new natural gas requiring processing by the average regional construction costs per MMcf processed per day.

Gas Plant Construction $Costs_R$ (Million $) = Net Natural Gas Requiring New Processing $Capacity_R$ (MMcf/yr) /365/ Max Plant Utilization $Rate_R$ * Avg construction costs per MMcf $Capacity_R$ (Million $)

e. Pipeline Construction: Pipeline construction cost source data are based on the national average capital cost per well[44]. Therefore, pipeline construction costs due to the construction of new wells is calculated as the number of new wells multiplied by the average regional pipeline construction cost per well.

Pipeline Construction $Costs_R$ (Million $) = (New Natural Gas Wells (#), New Oil Wells (#)) * Avg Pipeline Construction Cost per $Well_R$ (Million $)

7.2 Results Presentation

The third tab in the model, "Results," presents a summary of the user inputs and both a summary and detailed listings of the results of the import substitution and construction impacts by aggregated industries. Examples of the four results tables are shown below (Tables 3-6). The tables shown here correspond to the prototype model using aggregated sample data from Region 1: New York, Ohio, Pennsylvania, and West Virginia. The prototype model and its corresponding results tables were aggregated into 6 industries but the final model for this project and its corresponding results include 33 industries – see Appendix B.

Table 3 reports Import Substitution Impacts. This includes total output impacts for each industry, which are divided into the two components of intermediate inputs and value added. Value added is further sub-divided into its separate components of employment compensation, proprietor's income, other property type income, and indirect business taxes.

[44] See Section 5 for data source references.

Table 3. Import Substitution Impacts

[redacted]

Table 4 reports construction impacts. Once again, results are reported for total output impacts but have also been sub-divided into their respective components as done in the first table.

Table 4. Construction Impacts

[redacted]

Tables 5 & 6 report the tax impacts for import substitution and construction respectively. Impacts are given for enterprises (corporations), Federal Government Non-Defense, and State/Local Government Non-Education categories. The sources of these impacts are given in the columns and include employee compensation, proprietary income, household expenditures, enterprises, and indirect business taxes which can be summed to get the total tax impact.

Table 5. Import Substitution Tax Impacts

[redacted]

Table 6. Construction Tax Impacts

[redacted]

7.3 Other Model Tabs

There are two primary data tabs, "NG Data Sheet" and "Oil Data Sheet." These tabs hold state-level source data on production volumes, prices, well counts, trade activity and processing capacities, all of which have been aggregated to the model regions. These tabs also hold industry-level data used to transform producer prices to purchaser prices and vice versa.

The "Data Link" tab is used as the bridge between the user inputs entered on the "Inputs" tab and the input-output modeling which occurs within the model. A key component of this tab is the Oil and Gas Price Ratio (cells B9:C9). This ratio is necessary to adjust the composite price of oil and natural gas used in the model. The total consumption of oil and natural gas in the original setup is made up of both domestic oil and natural gas and internationally imported oil and natural gas. Domestic prices are not equal to the prices of the international imports. The overall price of oil and natural gas is therefore a weighted average of the domestic price and the price of international imports. When the model is run to determine potential impacts, the overall price of oil/natural gas will change because the amount of domestic oil and natural gas being produced is now larger and international imports decrease. Therefore, the weights on the overall price of oil and natural gas will be different. These changes should be reflected in an adjustment of the overall price. The calculation for the ratio is: $\frac{P_n}{P_0}$ where $P_n = \left[\frac{Pi(Qi+\Delta Qi)+Pd(Qd+\Delta Qd)}{(Qi+Qd)}\right]$ and $P_0 = \left[\frac{PiQi+PdQd}{(Qi+Qd)}\right]$

Table 7. Price Ratio Parameter Definitions

	Natural Gas	Oil
Pi	Weighted Average domestic and international import prices	
Qi	Demand - Domestic Production	
Pd	Wellhead Price	Refiner Price minus margins
Qd	Minimum of Domestic Production and Domestic Demand	
ΔQi	Offset Imports	
ΔQd	Domestic Production minus change in exports	

All remaining tabs represent various steps in the input-output modeling of the impacts related to increased natural gas and oil production and the generation of the results tabs presented above.

Section 8.0 Model Implementation Plan

8.1 User Instructions

The model allows for the analysis of increased natural gas and/or oil production within a single region. The current version of the model, as noted in Section 4.0, does not capture the impact on a region caused by production increases in a different region. Therefore, the model is run, and the impacts should be assessed, on an isolated, single-region basis.

To begin using the model, users have two options. First, the user can select a region map shown on the tab titled "Regions." This will jump the user to the region selection drop-down on the "Inputs" tab, but will not alter the region selection based on the map selected – the user still must select a region. Alternatively, the user can begin on the "Inputs" tab in cell F10 (located in the box "Increased Regional Production") and select an analysis region from the drop-down menu.

All user inputs are entered in the box "Increased Regional Production" located on the "Inputs" tab. In this box, all cells requiring user inputs are highlighted in orange; yellow fields represent source and/or calculated data.

To calculate the potential impacts of increased domestic natural gas and oil production within the selected region, the user first determines the level of increased production for which they want to assess the impacts and enters these values in cells H10 and I10 for natural gas (MMcf/yr) and/or oil (kbbl/yr), respectively. It is important to note that the values to be entered are levels of production *increases* and are <u>not</u> levels of <u>total</u> production. Additionally, the model limits production increases to 25 percent of 2006 well withdrawals (cells I24:I25).

In the next row down, the user can select the average well depth for the analysis region from a drop-down list. For natural gas wells, there are eleven depth options ranging from 0-20,000+ feet/well as well as the option of a Coalbed methane (CBM) site. For oil wells, the user can select from the same well depth options available under natural gas. Once the user selects the average well depth for the region, the model returns the regional average well construction cost (thousand $/well) for the selected depth (cells H12:I12). This cost information will flow to the new well construction cost calculations that drive the construction impacts in the model.

The next input the user makes relates to the producer price received by the natural gas and/or oil industry for the increased production. In cells H13:I13, the model reports the regional average natural gas wellhead price ($/mcf) and the regional average oil price ($/bbl).

Lastly, the user enters the international trade feedback percent. This rate is arbitrarily set to a range of 0% - 20%. The model applies this rate to the value of offset international imports and reduces the regions foreign export final demand for each of the modeled industries.

As noted in the previous section describing the construction of the model, data on regional production, supply and demand are located in box "Regional Information", calculation steps that convert user entered production increases (volume units) to industry output (dollars) that will drive the model are in box "Production Results" and information on new wells and plants as well

as construction costs are in box "Construction Cost Results". It is important to note that the values presented in "Production Results" and "Construction Cost Results" do not represent full production impacts.

To calculate economy-wide potential impacts of increased natural gas and/or oil production and related construction costs, the user must click the button "Generate & View Impact Results" located at the top of the "Inputs" tab. This button runs the input-output model to estimate total impacts and redirects the user to the top of the "Results" tab. While users can view results without clicking the "Generate & View Impact Results" button, clicking this button allows the spreadsheet model to access the input data from previous computations, edit the appropriate Use and Make tables along with appropriate final demand and output values, and carry out the computations described in the above Input-Output Model and Accounting Framework section to generate the total impacts of the increase in domestic production.

As shown in Section 7.2, the "Results" tab summarizes the results in tabular form. One set of output tables will present annually occurring impacts by industry[45], and a second set will present construction impacts stimulated by the initial expansion in domestic output. Output table information includes:

1. Input data summary
2. Summary impact results
3. Output impacts by industry
4. Value added by industry
5. Income impacts by industry
6. Employment impacts by industry
7. Tax effects by type and source of tax

8.2 Anticipated Model Applications

The goal of this analysis is to provide an easy-to-use, flexible model that allows users to assess the potential impact of increasing domestically produced natural gas and/or oil. The model was designed to offer as much flexibility to the user as possible, enabling a high level of user control, easily allow for multiple runs against a range of scenarios, and produce results that can easily be incorporated in report form.

It is anticipated that the model will be used to analyze potential impacts of varying levels of EPAct supported production increases as well as non-EPAct changes in domestic natural gas and oil production. This latter capability is possible because the model will retain the existing industry structure thus allowing for the calculation of impacts derived from increased domestic production using existing technologies. A caveat of modeling EPAct 999-related production increases is that the introduction of EPAct 999 technologies may alter the production function of the oil and natural gas industries. These changes will not be captured in this project's model as

[45] The prototype model and its corresponding results tables are aggregated into 6 industries but the final models for this project and their corresponding results will include 33 industries. Industry aggregation schema is detailed in Appendix B

this model will reflect the production function employed by present-day industries. Incorporating production function changes driven by the adoption of EPAct technologies is a potential area of future, follow-on research.

Appendix A: The Input-Output Model

Input-output analysis is based on the inter-industry sales and purchases relationships that exist in every economy. IO analysis characterizes an economy by describing these flows of goods and services between industries, institutions, and the final market.

François Quesnay (1694-1774), a French physician turned economist was the first to use this type of system to describe the economy. One of his main works, *Le Tableau Économique* (1758), contained an early, much less sophisticated version of a multi-sector input-output system. He aimed to show diagrammatically the flow of money in a primarily agrarian economy. Later, forms of this technique would be expounded upon by such great economic minds as David Ricardo, Karl Marx, and Léon Walras.

However, it wasn't until the late 1930's that Wassily Leontief (1906-1999), a Russian-born American economist, developed the analytical framework that would become modern input-output analysis. For this substantial contribution to the field he was awarded the Nobel Prize in Economic Science in 1973. In more recent years, input-output analysis has been extended to deal with such things as energy consumption, environmental factors, and employment impacts. It can now also be extended to consider interregional and multiregional analyses.

Methodological Basis

The statistical foundation of IO analysis is essentially an accounting framework. The basis of any type of IO system is the transactions matrix. The transactions matrix is a means of ordering all inter-industry sales (outputs) and purchases (inputs) — the economic transactions that occur in the economy — during a given time period. Each column of this matrix consists of the values of the inputs required by a given industry to produce its output. Each row consists of the values of the industry's outputs distributed throughout the economy. This transactions matrix only reports the intermediate goods and services being exchanged among industries.

Additionally, a full input-output table also includes a few additional rows (value added) and additional columns (final demand). The value added rows include information about the non-industrial inputs of production, such as labor. The final demand columns show the sales by each industry to a final market, such as consumption, investment, government purchases, and net exports. An example of an input-output table is produced below in Figure 1.

Transactions Table

				Final Demand						
		I1	I2	C	G	I	E	M	X	Gross Product
	I1	0.3	0.5	0.6	0.4	0.1	0.5	-0.2	2.2	1.4
	I2	0.7	0.2	0.3	0.1	0.8	0.4	-0.5	2	1.1
Value Added	P	0.8	0.7							
	W	0.4	0.6							
	X	2.2	2							
	Gross Income	1.2	1.3							2.5

Figure A1: *Accounting Foundations of IO Analysis*

Notation
Z : transactions matrix
$\mathbf{z_{ij}} \in \mathbf{Z}$: dollar flow of commodities from industry i to industry j on current account
$\mathbf{P_j}$: profits for industry j
$\mathbf{W_j}$: wages and salaries for industry j
$\mathbf{v_j}$: value added for industry j
$\mathbf{C_i}$: value of flows of commodities from industry i to consumption
$\mathbf{G_i}$: value of flows of commodities from industry i to government expenditures
$\mathbf{I_i}$: value of flows of commodities from industry i to investment
$\mathbf{E_i}$: value of flows of commodities from industry i to export sales
$\mathbf{M_i}$: value of imports of commodities for industry i
$\mathbf{f_i}$: value of flows of commodities from industry i to category k of final demand (consumption, government expenditures, investment, and export sales)
$\mathbf{X_i}$: output of industry i
$v_j = P_j + W_j$

$f_i = C_i + G_i + I_i + E_i$

Balance Equation for Output

$$\left(\sum_j z_{ij} \right) + C_i + G_i + I_i + E_i = X_i \forall i, i = 1,..., n$$

Balance Equation for Input

$$\left(\sum_i z_{ij} \right) + P_j + W_j + M_j = X_j \forall j, j = 1,..., n$$

Total Output

$$\sum_i \sum_j z_{ij} + \sum_i \left(C_i + G_i + I_i + E_i\right) = \sum_i X_i$$

Total Input

$$\sum_j \sum_i z_{ij} + \sum_j \left(P_j + W_j + M_j\right) = \sum_j X_j$$

To make economic sense, total outputs must equal total inputs. Then, we can see that:

$$\sum_i \sum_j z_{ij} + \sum_i \left(C_i + G_i + I_i + E_i\right) = \sum_j \sum_i z_{ij} + \sum_j \left(P_j + W_j + M_j\right)$$

$$\sum_i \left(C_i + G_i + I_i + E_i\right) = \sum_j \left(P_j + W_j + M_j\right)$$

C + I + G + E = P + W + M

C + I + G + E – M = P + W

The left hand side of this final equation is gross national product and the right hand side is gross national income.

Technical Coefficients (a_{ij})

<u>Assumptions</u>

1. Interindustry flows from *i* to *j* in a given time period depend solely on the total output for sector j in that same time period.
2. The technical coefficients are constant and measure fixed relationships between an industry's output and its inputs.
3. Production operates under constant returns to scale (CRS).
4. IO analysis requires that an industry uses inputs in fixed proportions.

$$a_{ij} = \frac{z_{ij}}{X_j}$$

The technical coefficient, a_{ij}, can be interpreted as the dollar's worth of input from industry i per dollar's worth of output of industry j. We can now define the technical coefficients matrix for an n-industry economy, A:

$$A = \begin{bmatrix} a_{11} & a_{12} & . & . & . & a_{1n} \\ a_{21} & a_{22} & . & . & . & a_{2n} \\ . & . & . & & & . \\ . & . & & . & & . \\ . & . & & & . & . \\ a_{n1} & a_{n2} & . & . & . & a_{nn} \end{bmatrix}$$

Using the numbers above in Figure 1, the technical coefficients matrix is defined as:

$$A = \begin{bmatrix} .1364 & .25 \\ .3182 & .1 \end{bmatrix}$$

Now, if we let Y_i be industry i's sales to final demand:

$Y_i = C_i + G_i + I_i + E_i$

Then we can write that:

$$X_i = z_{i1} + z_{i2} + \ldots + z_{in} + Y_i$$

Using the equation for technical coefficients above:

$$X_i = a_{i1}X_1 + a_{i2}X_2 + \ldots + a_{in}X_n + Y_i$$

By manipulating this equation in matrix form we can define the complete system as:

$$(I\text{-}A)X = Y \qquad \text{or} \qquad X = (I\text{-}A)^{-1}Y$$

where, I corresponds to the (nxn) identity matrix and $(I\text{-}A)^{-1}$ is called the Leontief inverse.

The Leontief inverse referencing Figure 1 is:

$$(I - A)^{-1} = L = \begin{bmatrix} 1.28997 & .3583 \\ .45608 & 1.2378 \end{bmatrix}$$

To show the dependence of the gross outputs on the values of the final demands we can define the elements of the Leontief inverse as l_{ij} and write the equation:

$$X_i = l_{i1}Y_1 + l_{i2}Y_2 + \ldots + l_{in}Y_n$$

Open or Closed Model

The IO model can either be open or closed with respect to households. If our project goal is to model the direct, indirect, and induced impacts of domestic oil and natural gas production then we are necessarily considering a model that it closed with respect to households.

The difference between an open model and a closed model is that households are exogenous in the open model and endogenous in the closed model. In a closed model, households are treated as part of the production sector and are therefore economically connected with all other parts of the transactions matrix. This addition adds one extra row and column to the transactions matrix, the matrix of technical coefficients, and the Leontief inverse. The household sector can be thought of as buying consumer goods from and selling labor to all other industries.

Strengths

- IO models provide a large amount of information in a concise and easy to understand form. They present a comprehensive picture of the economy and its inter-industry relations.
- IO analysis is transparent; it does not rest on as many assumptions and parameters as some of the models that are discussed later in this document.
- Extremely useful in analyzing the impact of a change in any sector on the output of others.

- One main attribute of IO analysis is its descriptive analytical power. It has predictive capabilities in that it can estimate both direct and indirect impacts as they are tracked through the economy.
- IO analysis analyzes changes and impacts on an industry-by-industry level, tracing the flow of dollars between industries. Therefore, it is possible to have a very precise calculation of the economic impacts to the economy.
- The extension of an IO model to an interregional or multiregional framework is straightforward.

Weaknesses

- Constructing transactions matrices can be costly and time-consuming. These data, however, are often collected by government agencies and are available for use but with some significant time lag.
- An IO matrix gives a static view of the economy and can make structural projection difficult. However, with a significant level of complication, input-output models can be transformed into dynamic models. With required data and economic assumptions, it is also possible to make changes to the initial IO model in order to model different time periods by assuming that technical coefficients are stable over time.
- IO analysis does not allow for interaction between supply and demand. Prices are fixed in both goods and labor.
- IO models are not set up for any supply or capacity constraints; however, these could be handled with the external processing of data.
- The linear relationships assumed in IO analysis do not allow for externalities or increasing/decreasing returns to scale
- There is no statistical test to check the model specification.

Geographical Scale

Most available IO data are collected and published on a national scale. These national data can be used to estimate regional data using one of several regionalization techniques. The regionalization technique of greatest relevance to this project is the regional purchase coefficient (RPC) technique used in Impact Analysis for Planning (IMPLAN), from whom project data has been obtained.

RPC Method

The regional purchase coefficient is the proportion of the regional demand for a good or service that is fulfilled by production within the region, as opposed to being fulfilled by imports from other regions.

Notation

$\boldsymbol{R^M}$: regional purchase coefficient for region M

$\boldsymbol{S^{MM}}$: amount of good produced locally in region M (amount shipped from region M to itself.)

$\boldsymbol{S^{LM}}$: amount of the same good produced in region L and shipped to region M. (If this were a multi-region setup L corresponds to the rest of the 'world' not just one other region.)
A general equation of an RPC for a region *M* can then be defined as:

$$R^M = \frac{S^{MM}}{S^{MM} + S^{LM}}$$

IMPLAN uses a more sophisticated form of this equation that estimates the RPC as a function of the wage ratio, the ratio of 'other costs', the output ratio, the weight/value ratio of the good, the ratio of the number of user's of a good, the ratio of the number of producers of a good, and the land area ratio of each region.

Data Requirements

- Sales and purchases data, disaggregated by industry and region
- Final demand data by industry and region
- Household consumption data by industry and region
- Household compensation data by industry and region
- Data on the impact scenario

Applications

There is a voluminous literature available on the uses and applications of IO analysis. The literature ranges from many different policy implications to environmental applications (Duchin 1992 and Hubacek et al. 2002) with general studies on many different countries, a few examples being Haddad and Hewings 2000 and Cho et al. 2000. Studies have even been done to predict the effects of sudden changes to the economy (Okuyama et al. 1997 and the forthcoming study of Lahr et al.). There is also a literature in which IO analysis techniques are advanced and changes in regional structure are further explored (Rey and Jackson 1999, Jackson et. al. 1989).

Appendix B: Industry Aggregation Schema

Project Model Sector #	*Sector Name*	*IMPLAN Sector Code*	*Related BEA Sectors*
1	Agriculture, forestry, fishing and hunting	1-18	11
2	Oil and gas extraction	19	2110
3	Coal, metal ores & non-metallic mineral mining, quarrying & support activities	20-26, 29	212X
4	Drilling oil and gas wells	27	213111
5	Support activities for oil and gas operations	28	213112
6	Power generation and supply and water, sewage and other systems	30, 32	221X
7	Natural gas distribution	31	2212
8	Manufacturing and industrial buildings	37	23621
9	Water- sewer- and pipeline construction	40	23711, 23712
10	Other new construction, including maintenance and repair construction	33-36, 38-39, 41-45	23X
11	Construction and mining machinery manufacturing	259-260	3331X
12	Oil and Gas Field Machinery and Equipment Manufacturing	261	333132
13	Motor vehicle manufacturing	344-345	3361
14	Other Manufacturing	46-258, 262-343, 346-389	3X
15	Wholesale Trade	390	42
16	Retail Trade	401-412	4A
17	Air, Rail & Water Transportation	391-393	481-483
18	Truck Transportation	394	484
19	Pipeline Transportation	396	486
20	Transit and Sightseeing Transportation & Transportation Support Services	395, 397	485,487
21	Postal Services, Couriers and Messengers & Warehousing and Storage	398-400	49
22	Information	413-424	51
23	FIRE & Rental and Leasing Services, excl Commercial and Industrial Machinery and Equipment Rental and Leasing	425-433, 435-436	52_3X
24	Commercial and Industrial Machinery and Equipment Rental and Leasing	434	5324
25	Architectural, Engineering, and Related Services	439	5413
26	Environmental and other technical consulting	445	5416X
27	Other Professional, Scientific, and Technical Services	440-444, 446-450	541X
28	Management of companies and enterprises	451	55
29	Administrative and Support and Waste Management and Remediation Services	452-460	56
30	Educational services, health care, and social assistance	461-470	6
31	Arts, entertainment, recreation, accommodation, and food services	471-481	7
32	Other services, except government	482-493	8
33	Government and Non-NAICS	494-509	92

Appendix C: Acronyms

AEO	Annual Energy Outlook
AMIGA	All-Modular Integrated Growth Assessment Model
ARI	Advanced Resources International, Inc.
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
CBM	Coal-bed Methane
CGE	Computable General Equilibrium
DOE	Department of Energy
EEA	Energy and Environmental Analysis, Inc.
EIA	Energy Information Administration
EMM	Electric Market Module
EPAct	Energy Policy Act
EPSIM	Energy Policy Socioeconomic Impact Model
FERC	Federal Energy Regulation Commission
GTI	Gas Technology Institute
IMPLAN	Impact Analysis for Planning
IO	Input Output
IOGCC	Interstate Oil and Gas Compact Commission
IPAA	Independent Petroleum Association of America
JAS	Joint Association Survey
JEDI	Job and Economic Development Impact

LNG	Liquid Natural Gas
MUGS	Model of Unconventional Gas Supply
NAICS	North American Industry Classification System
NEMS	National Energy Modeling System
NERC	North American Electric Reliability Council
NETL	National Energy Technology Laboratory
NGPL	Natural Gas Plant Liquids
NPC	National Petroleum Council
NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
OOIP	Original Oil in Place
OSAP	Office of Systems, Analyses and Planning, NETL
PADD	Petroleum Administration for Defense District
RD^3	Research, Development, Demonstration and Deployment
RPC	Regional Purchase Coefficient
RPSEA	Research Partnership to Secure Energy for America
SAM	Social Accounting Matrix
SCNGO	Strategic Center for Natural Gas and Oil, NETL

Appendix D: Glossary

Absorption Table – A coefficient form of the Use table derived by dividing each element of the Use table by total industry output.

Byproducts Table – A coefficient form of the Make table derived by dividing each element by the Make table row totals.

Crude Oil – Unprocessed oil that has come out of the ground

Direct Impact – The initial change in the industries to which a final demand change was made.

Final Demand – The purchases of goods and services for final consumption.

Import Substitution – The process of replacing imports with domestic production.

Indirect Business Taxes – These taxes include sales, excise, fees, licenses, and other taxes that are paid during the normal operation of a business. This includes all payments to the government except for income taxes.

Indirect Impact – The changes in inter-industry purchases that occur as they respond to the new demands of the industries that were directly affected.

Induced Impact – The changes that typically reflect the changes in spending from households as income changes due to the changes in production.

Input-Output Analysis – The manner in which an input output model is used to perform an economy-wide analysis for a given time period. The model is capable of examining inter-industry relationships as well as relationships between industries and final consumption.

Liquid Natural Gas (LNG) – Natural gas that has been converted to liquid form for ease of storage or transport.

Make Table – The matrix that contains the dollar value of each commodity or service that is produced by each industry. In this matrix, the rows are the industries and the columns are commodities.

Make Table – The make of commodities by industry; it shows each industry's production of goods and services.

Marginal Wells – Marginal wells can be either oil or gas wells. Marginal oil wells are those producing 10 or fewer barrels of oil per day. Marginal gas wells are those producing 60,000 or fewer cubic feet of gas per day.

Margins – The difference between producer and purchaser prices.

Producer Prices – The selling price received by a producer for goods and/or services produced.

Purchaser Prices – The price paid by the purchaser for a good or service. This price reflects the producer's price plus all applicable retail, wholesale and transportation costs.

Regional Purchase Coefficient (RPC) – A coefficient representing the proportion of local demand that is purchased from local producers.

Social Accounting Matrix (SAM) – A set of economic accounts which describe inter-industry relationships, transfers between institutions, as well as value added components for a given time period.

Use Table – The matrix that contains the dollar value of commodities and services purchased by each industry for use in the production process. In this matrix, the rows are the commodities and the columns are industries.

Value-Added – Payments made by industries to workers, interest, profits, and indirect business taxes.

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