1. Task - Collect and Report O&M Cost Data for Power Generation Technologies

This document and its companion data entry form spreadsheet (Technology.Data.xlsx) are intended to provide you with a set of instructions for completing the task of collecting and reporting economic data on (or your best estimates of) the annual operating and maintenance (O&M) expenditures of different types of power generation technologies that supply or are projected to supply electricity to the grid. The data collected and reported by you will be used by members of our research team to transform output from national energy-economic system model(s) to readable input data for the ECIO model.[1] The power generation technologies for which we seek economic data on annual O&M expenditures for include:

1. **Natural gas combined cycle (NGCC)**
2. **NGCC w/ Carbon Capture and Storage (CCS)**
3. Natural gas combustion turbine
4. Natural gas, combined heat, and power (CHP)
5. **Coal integrated gasification combined cycle (IGCC) w/ CCS**
6. Coal, CHP
7. **Steam coal**
8. **Steam coal w/ CCS**
9. **Pulverized coal (PC)**
10. **PC w/ CCS**
11. Diesel oil, combined cycle
12. Oil, CHP
13. **Nuclear**
14. Residual fuel oil
15. Biomass, wood
16. Landfill gas
17. **Solar PV**
18. **Concentrated/Central Solar**
19. Geothermal Power
20. Hydroelectric, conventional
21. Pumped storage hydro
22. **Wind**

Bolded power generation technologies should be considered **priority** technologies.[2]

[1] The ECIO model is an economic impacts forecasting model capable of generating industry-level estimates of changes in employment, labor income, and total output resulting from proposed shocks to the U.S. energy economy. The ECIO model currently functions as an extension of the U.S. energy-economic models available from the United States (U.S.) Energy Information Administration's National Energy Modeling System (NEMS) and the U.S. Environmental Protection Agency's Market Allocation (MARKAL) model. The model integrates a macroeconomic econometric forecasting model and an input-output accounting framework along derived forecast scenarios to generate impacts estimates of.

[2] Economic data on annual O&M expenditures for every technology included in the list is of interest to our team. However, we have classified some power generation technologies as priority technologies due to the nature of the

This document is designed to reach an audience that includes engineers and other non-economists. As such, in addition to providing you with a set of instructions for completing the requested task, background information including key concepts and the terminology generally used in economic modeling when classifying business is provided in Section 2. Concepts and terms are presented in such a way that should be transferable to your problem domain and help to clarify the economic input data we seek in the companion data entry form spreadsheet, which is detailed in Section 3. Section 4 describes the difference between *producer* and *purchaser* prices, which should be reviewed carefully before following along with the instructions for completing the data entry form in Section 5.

2. Classifying Business Activity

The lowest level of business unit that economists work with commonly is the establishment, which refers to a business activity at a given location.[3] Business activity includes both production and non-production (sales, management, etc.) activity. Because an individual company is a legal entity (of various kinds – partnerships, LLCs, corporations), it might have multiple establishments that are engaged in the same production activity OR multiple establishments that are engaged in different production activities. The company's establishments can be located at one or multiple locations.

The U.S. Bureau of the Census is responsible for primary economic data collection associated with establishments. Economic data for all of the activity that takes place at or is centered (not simply headquartered) at an establishment's location is reported to the Census, following the North American Industrial Classification System (NAICS) codes. Establishments report output levels and NAICS codes for primary and secondary commodities produced during the reporting period, normally a calendar year. Establishments also report the value of all of the materials and services that they purchase, the cost of labor (employee compensation), the cost of licenses, fees, etc. (payments to government), and gross operating surplus (GOS) to the Census. The Census then groups establishments into their respective NAICS-coded industries based on the information they report.

For our work, we will be focused on establishments who engage in the production of electricity. We assume that these establishments include all the various power generating technologies that supply or are projected to supply electricity to the grid. For the purposes of our data collection and compilation we treat power generation technologies (e.g., hydro, nuclear, etc.) separately based on their fuel type, and where applicable, based on the scale of their generation (e.g., utility-scale solar PV and residential scale solar PV) and their reported prime

processes and algorithms already developed to support the transcription of data from national energy-systems models to readable input for the ECIO model.

[3] This doesn't mean that all of the business activity conducted by an establishment has to take place physically at that location; it simply means that the business activity is centered on that location. For example, an establishment involved in the business activity of collecting and bundling used carpet to sell to a carpet recycling processor might have a single location for its central operations but many of its employees might spend the bulk of their time out in trucks at a variety of different collection site locations.

mover (i.e., primary electrical engine). Each individual power generation technology is treated as *though* it were a separate industry.

3. Economic Data Required

The economic data on annual O&M expenditures we seek follows an input-output (IO) accounting framework. The data we are specifically interested in obtaining for each power generation technology type included in the list on page 1, are outlined below:

1. An accounting of all of the primary and secondary commodities produced and sold by the specific power generating technology type in a reporting year.
    a. In our case, electricity will be the primary commodity produced. All other commodities are should be considered secondary commodities.
2. The values of the commodity inputs required to produce the primary and secondary commodities, including the value of the material inputs and the services.
    a. The values of the commodity inputs required to produce primary and secondary commodities can be thought of as the individual O&M expenditures corresponding to each commodity input, where the sum of the individual O&M expenditures by input commodity is equal to the total O&M expenditures for the power generation technology type considered. IO accounting requires details on **input expenditures *by commodity*** *(especially fuel by type),* not simply the sum of these costs.
3. The value of the value-added (VA) components necessary to produce the primary and secondary commodities, including:
    a. The cost of labor (employee compensation)
    b. Other Value Added (OVA) = Payments to government + Gross operating surplus (GOS), where GOS includes profit
4. The dollar value of the Total Industry Output (TIO)
    a. TIO is the sum of the values of all of the commodities (primary and secondary) produced and sold by an industry.
    b. TIO for a specific power generation technology type can be thought of as the value of the electricity produced plus the value of any secondary commodities produced by the power generating technology, in a single year. In other words, TIO represents total sales.

We seek information on 1. through 4. above as they relate to *Current Account Expenditures*, which include annually recurring expenditures, most of which will increase or decrease with increases or decreases in production. Capital costs related to new construction and durable machinery or equipment with multi-year lifespans should **not** be considered current account expenditures. As such, economic data on capital costs associated with new construction or the purchase of durable machinery/equipment should not be included.

A Note on IO Accounts

Due to the "double-entry" nature of the IO accounting framework, which forms the basis of the economic data we seek, TIO (4.) is equal to the sum of the values of all commodities (primary and secondary) produced and sold by an industry (1.), which is equal the value

of the commodity inputs required to produce the commodities (2.) plus the values of the different components of VA (3.), including employee compensation, payments to government, and GOS. Commodity input values, as well as the values assigned to the components of value added, represent the annual input costs of production (i.e., the O&M expenditures for each power generation technology). For this reason, if we have a value for total industry output and employee compensation, as well as values for each commodity input required, we could compute other value added (OVA) (i.e., payments to government or GOS). For profitable industries, the value of all of the inputs (including value added) is equal to the value of the outputs.

4. Prices for the Economic Data (Producer vs. Purchaser + Margins)

IO accounts are denominated in *producer* prices. Sometimes called f.o.b. prices, *producer* prices are the prices received by a seller at the "factory gate." However, sometimes the price information reported by an establishment is in *purchaser* prices. By definition, *purchaser* prices are equal to *producer* prices *plus trade and transport margins*. Margins capture the additional costs of storage, transportation, and wholesale and retail trade to the price the producer receives for the commodity. Together the *producer* price and the tr*ade and transport margins* compose the *purchaser* price. *The trade and transport margins are effectively the prices associated with delivery.* Distinguishing between *producer* and *purchaser* prices is critically important when assigning industry input costs to ECIO industrial sectors. sectors.

For the purposes of our work, we are interested in economic data measured in *producer* prices. However, we realize there may be instances where data are only available in *purchaser* prices and margins may or may not be known. To assist with the data entry requirements above and our need to have them in *producer* prices, we have set up the spreadsheet to be usable if producer prices are available OR if only purchaser prices (w/ and w/o margins) are available for the generating technologies. More information is available in the following section.

5. Outline of and Instructions for Completing the Data Entry Form

The data entry form spreadsheet (Technology.Data.xlsx) has several pages: 1. *File Contents*, 2. *Definitions*, 3. *Annual Expenditures Summaries*, 4. *Data Entry Form* and 5. *Editable Data Entry Form*. The *File Contents* page describes the information contained on each page of the companion spreadsheet. The *Definitions* page provides you with select key definitions including the definitions for the different components of value added (VA), and industrial sectors related to the generation, transmission, and distribution of electricity.

The *Annual Expenditures Summaries* sheet is provided to assist you with the organization of the data you have collected (or your best estimates) for each of the different power generation technology types. Power generation technologies are listed in Column F.[4] Input either your data-based or best-estimates of the annual expenditures by technology type in Column E. Use Columns B, C, and D to assign set percentages to the amount of the annual O&M expenditures

[4] This list of technologies included is identical to the list on page 1 of this document.

represented by material (non-labor) input costs [Column B], labor (employee compensation) [Column C] and other value added (VA) [Column D]. [5]

Recall from earlier, due to the "double-entry" nature of IO accounts, the sum of annual expenditures is equal to total industry output, which is equal to the value of the commodity (material and service) non-labor inputs, plus employee compensation (labor costs), plus OVA. As such, the percentages assigned to annual non-labor input costs, annual labor costs, and OVA should sum together to equal 100%. It is acceptable to leave any row blank if you have no basis whatsoever for estimates related to the annual expenditures of for technology type listed in the corresponding row. However, a good guess is preferred to no information. Lastly, it isn't necessary to report precise estimates. Round numbers are preferred.

The *Aggregation Scheme* page provides the concordance between the ECIO model's industrial sectors and NAICS Codes. This sheet is provided to assist you in assigning the values of the different material and service, [non-labor] input costs to the correct ECIO sector for each technology type you report information on. This information should be reviewed carefully before proceeding to fill in the requested data.

> *If you need assistance in assigning inputs to commodity sectors, you may click on this link which will take you to a NAICS Lookup webpage. Confusion sometimes arises for oil and gas inputs. Gas input to the Power Generation (PG) sector corresponds to ECIO Sector 2, Oil and gas extraction, while oil input to Power Generation corresponds to ECIO Sector 15, Petroleum and coal products.*

The *Data Entry Form* sheet is included to provide you with an illustrative example of how to report the economic data you have collected (or your best estimates of) the annual O&M expenditures for each of the different power generation technology types. The sheet follows the same layout as the *Editable Data Entry From* and is populated by the economic data we require for 1. through 4. above (see page 3), but for the 2018 U.S. Power Generation, Transmission and Distribution sector (PG,T&D) as a whole. Columns A and J provide more information on what the $ values listed in Columns B and H, represent respectively.

> *The ECIO margins "commodities" are identified on the fourth sheet of the data entry form by shaded names in light purple, commodities 17 – 23. The trade and transport margins are effectively the prices associated with delivery.*

The *Editable Data Entry Form* is a duplicate of the *Data Entry Form Example* with economic data on the PG, T&D industry removed. Copies of the *Editable Data Entry Form* should be created for each of the technologies from the *Annual Expenditures Summaries* sheet you reported information on (i.e., all non-blank rows). For each additional technology, create a duplicate of the *Editable Data Entry Form* and unprotect the duplicated page to input the data required, as outlined above.[6] If you need to unprotect the duplicated sheet, the password is *Fuel*. As with the *Annual*

[5] For example, if you estimate the annual expenditures of a natural gas combustion turbine to be $3.5 M and the annual non-labor input costs to be equal to approximately 60% of the turbine's annual expenditures, then you would input 0.6 or 60% in column B row 5.

[6] Please note, there are differences in some of the formulas between the Data Entry Form sheet and the Editable Data Entry Form sheet. It is important that you make copies of ONLY the Editable Data Entry Form sheet.

Expenditures Summaries sheet, a good guess is preferred to no information and round numbers are preferred in lieu of precise estimates.

To begin editing the *Editable Data Entry Form* sheet for a chosen technology, first choose one of the power generation technologies from the drop-down list (Column I Row 3). Rename the duplicated sheet as the name of the power generation technology chosen. To input the economic data, complete the following steps:

1. Input and assign values for 1. above (see page 3) in the Rows of Column I, corresponding to the ECIO sector whose description aligns with the description of the produced commodity.
2. Input and assign values for 2. above (see page 3) in the rows of Columns D, E, or F corresponding to the ECIO sector whose description aligns with the description of the commodities used. Which column (D, E, or F) you input values into will depend on whether the data you are reporting (or your best estimates) are measured in *producer* or *purchaser* prices. To assist with the data entry and our need to have data in *producer* prices, we have set up the spreadsheet to be usable if *producer* prices are available OR if only *purchaser* prices are available for the generating technologies. [7]
    a. If you know the *purchaser price* and have an estimate of the proportion or amount of the purchaser price represented by the producer price and the margins, enter the amounts of the producer prices and the margins into the respective rows of column D.
    b. If you know only the *producer* price for an input commodity and have no information on margins, enter the values for inputs in column E.
    c. If you know only the *purchaser price* of an input commodity and are unable to decompose to producer prices plus trade and transport margins, enter the values for inputs in column E.
    d. If you know the *purchaser price* an input commodity and are able to decompose to producer prices plus trade and transport margins, enter the values for inputs in column F.

    A few important notes: 1) The ECIO margins "commodities" are identified on the by shaded names in light purple, commodities 17 – 23. 2) If you enter values in columns E or F, be sure not to duplicate those values in Column D. 3) If you do anything that requires explanation of your values or decisions, please add explanatory comments to Column A, to provide sufficient annotation to assist in closer subsequent assessments by our team. 4) You will notice the rows of

[7] An example of with margins relating to the Data Entry Form sheet: If the input costs for coal, for example are in purchaser prices, then the purchaser price will be divided among the coal mining sector (Sector 3 in Column C) and the respective margins (e.g., transportation) in column C. The logic behind this is that IO models are "demand-driven." The demand for coal by a power generation facility becomes demand not only for the coal commodity, but also for the transportation services required to deliver the to the facility. If we were to allocate the purchase price to only the coal mining sector (Sector 3), however, we would be overestimating the demand for coal (by the amount of the margins), and if we were to allocate the entire purchase price to, say, rail transportation, we would be overestimating the demand for rail transport (by the value of the coal commodity being shipped).

Columns B and C have been greyed out. Our team will use these rows and fill in the necessary information using reported values from the other columns.

3. Input the values for 3. above (see page 3) — into the following cells:
    a. Value for employee compensation ($) in the merged cell Columns E/F Row 46
        i. Employee compensation includes wages, salaries, and benefits (not just wages and salaries).
        ii. If you need help estimating values for employee compensation, utilize the tool in the green outlined box at the bottom of the page. Input values for either employee compensation per employee or total compensation.
    b. Value for OVA ($) in the merged cell of Columns E/F Row 47.
        i. If you need assistance estimating the amount of annual expenditures represented by OVA, utilize the formula in the merged cell of Columns E/F row 47 from the *Data Entry Form* sheet. Copy and paste the percentages from the *Annual Expenditures Summaries* sheet for the technology you are reporting on into Column B, Rows 46 and 47.
        ii. If you do not need assistance, simply input the value for OVA into the corresponding cell.
    c. The call corresponding to Total Value Added should automatically populate.

4. The value for 4. above (see page 3) should automatically populate in Column I Row 44.
    a. The validity check will produce an error if the total expenditures you report, do not match the TIO.

The information you reported in the *Annual Expenditures Summaries* sheet can also be leveraged to fill in the necessary data requested above.

Please direct questions to Randy Jackson <rwjackson@mail.wvu.edu> or Amanda Harker Steele < Amanda.HarkerSteele@netl.doe.gov >

Appendix

The ECIO model is an econometric input-output model. The accounting framework that underlies any input-output model, makes the simplifying assumption that inputs used by industries are proportional to the outputs produced. In economics, this is called a linear (or Leontief) production function. When the Census groups establishments into their respective NAICS-coded industries based on the information they collect from surveys, they have two sets of interrelated information for each industry:

1. Dollar costs of annual industry purchases (by input commodity – especially fuel by type, and employee compensation)
2. Dollar value of every commodity the industry produces annually

This information is compiled to produce what are referred to as the national annual input-output accounts, which take the form of a Use table and a Make table, final demands by commodity, and VA by industry. Figure 1 below shows a high-level view of the accounting framework:

Figure 1. General Depiction of the Input-Output Accounting Framework

	Commodities	Industries	Final Demand	Totals
Commodities		U	e	q
Industries	V			g
Primary Inputs		va		
Totals	q'	g'		

- U = the *Use* table: row commodities used by column industries
- V = the *Make* table: column commodities produced by row industries
- e = column final demand activities use of row commodities
- q = column vector of total commodity use
- g = column vector of total industry output
- va = column industry payments to row value added components, typically compensation, payments to governments, and gross operating surplus
- $\mathbf{i}$ is a summing vector of appropriate dimension
- $'$ indicates transpose
- $\hat{}$ indicates diagonalization

Values in the Use table (U) include the values of commodities produced by industries. As such, they represent the values for 2. above. Values included in the Make table (V) include the values of the commodities produced by different industries. As such, they represent the values for 1. above. There will be one column in the Use table (U) and one row in the Make table (V) for each industry. Because industries are named according to dominant commodity output, there will be at least as many commodities as industries, and often one or two commodities that are no industry's dominant commodity produced (e.g., scrap). We often use this industry-specific information in a standardized format.

That is, from the Use table we derive a set of cost shares (input-output coefficients) with values between zero and one, each of which represents the dollar value of the output of each commodity *per total dollar* of output from the industry (output-output coefficients). Because all costs are included in the accounts, the sum of these coefficients is 1.0. From the Make table, we

derive the absolute dollar value of industry output of each commodity produced, the sum of which would be equal to the total output of the industry (for the relevant year). If we have the standardized representation of the make table, we can rescale it to any level of production, assuming linearity in production coefficients. Make tables can be standardized by their row or column sum, yielding either commodity shares of industry output or industry shares of commodity output, depending on the purpose to which the result will be put. Within the ECIO technology mix, our goal is to be able to transform output dollars to input dollars by commodity input.

The end goal of this exercise is to establish the by-power generation technology source information in such a way that after compilation we will have the value of inputs used by each power generation technology (industry) per output dollar for each power generation technology included in the list. We can then appropriately weight each power generation technology for a given year to estimate current account expenditures for the aggregate power generation fleet (i.e., the sum of all power generation technologies contributing to the supply of electricity in a given year).