NATIONAL ENERGY TECHNOLOGY LABORATORY

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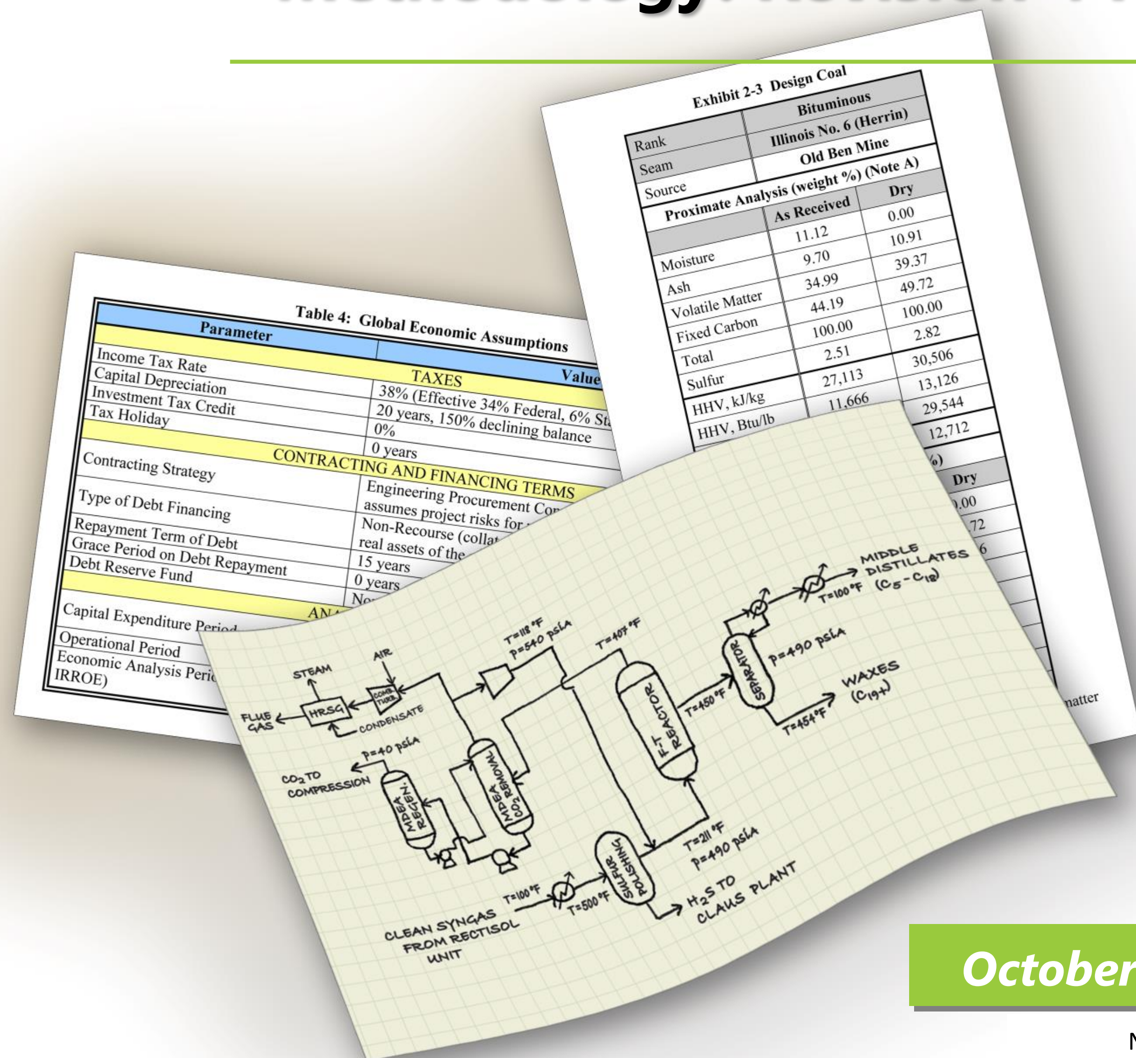
QUALITY GUIDELINES FOR ENERGY SYSTEM STUDIES

Capital Cost Scaling Methodology: Revision 4 Report



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Quality Guidelines for Energy System Studies
Capital Cost Scaling Methodology: Revision 4 Report

Final Report

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Acronyms and Abbreviations

acfm	Actual cubic feet per minute
ACI	Activated carbon injection
AGR	Acid gas removal
ASU	Air separation unit
BEC	Bare erected cost
BOP	Balance of plant
C	Coefficient in equations
CFBC	Circulating fluidized bed combustion
Circ.	Circulating
CO_2	Carbon dioxide
COS	Carbonyl sulfide
CTG	Combustion turbine generator
DOE	Department of Energy
DSI	Dry sorbent injection
Exp	Exponent in equations
FGD	Flue gas desulfurization
ft^3	Cubic feet
GE	General Electric
gpm	Gallons per minute
Hg	Mercury
HGCU	Hot-gas-cleanup unit
HP	High pressure
HRSG	Heat recovery steam generator
I&C	Instrumentation and control
IGCC	Integrated gasification combined cycle
ISO	International Standards Organization
kW	Kilowatt
lb/hr	Pounds per hour
LT	Low temperature
MDEA	Methyldiethanolamine
MMBtu/hr	Million British thermal units per hour
MVA	Mega volt-amps
MW	Megawatt
N/A	Not applicable
NETL	National Energy Technology Laboratory
NGCC	Natural gas combined cycle
O_2	Oxygen
PC	Pulverized coal
PRB	Powder River Basin
psia	Pounds per square inch absolute
QGESS	Quality Guidelines for Energy System Studies
RBEC	Reference plant bare erected cost in equations
RC	Reference cost in equations
RCon	Reference plant's contingency in equations
RP	Reference parameter in equations
RTPC	Reference total plant cost for subaccount in equations
SC	Scaled cost in equations
SCon	Scaled plant's contingency, percent
SCR	Selective catalytic reduction
SDE	Spray dryer evaporator
SP	Scaled parameter in equations
STG	Steam turbine generator
TPC	Total plant cost
TPD	tons per day
USC	Ultra-supercritical
WGS	Water gas shift

1 Foreword

The National Energy Technology Laboratory (NETL) regularly updates legacy analysis with new studies and cases as the Department of Energy objectives change, technology performance improves, costs are reduced, regulations change, market drivers are established, fuel prices fluctuate, and any number of other relevant factors vary in the market. As legacy studies are updated by NETL, the underlying performance and cost of the cases presented changes, and as such, the methods for interpreting and scaling the cost estimates change. Therefore, it is important that NETL maintain public guidance documents associated with different sets of cost estimates that delineate how a specific set, based on report vintage and/or year published, should be scaled. This Quality Guidelines for Energy System Studies (QGESS) report, providing guidance on capital cost scaling, should generally be applied to NETL case costs included in the report “Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity Revision 4” (Bituminous Baseline Revision 4), [1] or any cases derived from the cases presented in the referenced report.

2 Introduction

Costs are frequently required as part of systems analysis work at NETL. Many of the cost results provided as part of systems analysis work were created with the use of scaling, since obtaining new vendor-supplied cost quotes for each category developed by NETL would be prohibitively time consuming and costly. Additionally, many of the technologies being investigated by NETL have not progressed far enough to have quotable costs.

The costs are scaled from a quote for a similar plant configuration by use of various equations that typically employ at least one process parameter (e.g., coal-feed rate, oxidant-feed rate) and often an exponent. The primary purpose of the exponent is to account for economies of scale (i.e., as equipment size gets larger, it gets progressively cheaper to add additional capacity).

The purpose of this section of the QGESS report is to provide a standard basis for scaling costs, with specific emphasis on scaling exponents. The intention of having a standardized document is to provide guidelines for proper procedures to reduce the potential of errors and increase credibility through consistency.

This document contains a listing of frequently used pieces of equipment and their corresponding scaling exponent for various plant types, along with their ranges of applicability. This document also details the equations to be used with each exponent.

The scaling exponents used in systems analysis work are logarithmically derived from previously obtained vendor supplied cost quotes using Equation 1.

$$Exp = \frac{\ln\left({RC_1}/{RC_2}\right)}{\ln\left({RP_1}/{RP_2}\right)} \qquad \text{Equation 1}$$

Where:

Exp – Exponent

RC – Reference Cost

RP – Reference Parameter

Exhibit 2-1 provides a listing of the categories used in this document and a description of the types of technologies to which the associated exponents are applicable. Exhibit 2-2 provides a listing of reference reports for the various categories. Since this document has been updated based on the recently released Bituminous Baseline Revision 4, this guidance is only applicable to those cases as of the publication of this QGESS. As future studies build on those Revision 4 cases, those future cases will also be subject to the guidance contained in this QGESS.

The listings are divided into three major technologies frequently analyzed at NETL: pulverized coal (PC), integrated gasification combined cycle (IGCC), and natural gas combined cycle (NGCC).

Exhibit 2-1. Category matrix

Category	Technologies
PC	
1	Supercritical[A] PC, air-fired, with and without CO_2 capture, Illinois No. 6 coal
2	Subcritical PC, air-fired, with and without CO_2 capture, Illinois No. 6 coal
IGCC	
3	Two-stage, slurry-feed, oxygen-blown gasifier with and without CO_2 capture, Illinois No. 6 coal
4	Single-stage, slurry-feed, oxygen-blown gasifier with and without CO_2 capture, Illinois No. 6 coal
5	Single-stage, dry-feed, oxygen-blown, up-flow gasifier with and without CO_2 capture, Illinois No. 6 coal
NGCC	
6	Natural gas, air-fired, with and without CO_2 capture

[A]In prior versions of this guidance document, ultra-supercritical (USC) PC plants were also included in this category, with the following direction: apply 10-percent process contingency to the line item PC Boiler & Accessories (Account 4.9), and a 15-percent process contingency to the line item Steam Turbine Generator & Accessories (Account 8.1). USC plants could be included in this category using the provided guidance for Revision 4 cases, but NETL reports have not publicly demonstrated application of this guidance to Revision 4 cases to date.

Exhibit 2-2. Representative reference cost estimates

Category	Technologies Report Hyperlinks
PC	
1	Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Revision 4 [1]
2	Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Revision 4 [1]
IGCC	
3	Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Revision 4 [1]
4	Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Revision 4 [1]
5	Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Revision 4 [1]
NGCC	
6	Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Revision 4 [1]

2.1 Limitations of Scaling Approach

It is important to note that when scaling costs, the technologies must be as similar as possible. For instance, if scaling a plant that fires Illinois No. 6, both the scaling exponents and the reference cost should be for a plant that fires Illinois No. 6. The same is true for the following specifications as well:

- Oxidant type (air or oxygen)
- Elevation/location (International Standards Organization [ISO], North Dakota, Montana, etc.)
- Plant type (sub-critical, supercritical, ultra-supercritical, etc.)
- Technology type (PC, IGCC, NGCC, etc.)
- Emissions control technologies (with/without CO_2 capture, with/without flue gas desulfurization [FGD], etc.)

For many of the items provided in this report, the approach presented scales on a single parameter for a given account. In reality, some accounts, particularly some of the major equipment items, may be impacted by more than one parameter. For example, a line item may be scaled on one or more flows/outputs but should, in reality, be scaled on multiple flows/outputs and on both pressure and temperature, or thermal duty and delta temperature. While the single-parameter approach can be used for high-level scaling, it is recommended that individual items/systems be scaled from the most similar reference possible, particularly for the cost drivers.

There are limitations on the ranges that can accurately be addressed by the scaling approach. There can be step changes in pricing at certain equipment sizes that may not be captured by the scaling exponents. Care should be taken in applying the scaling factors when there is a large percentage difference between the scaling parameters. This is particularly true for the major equipment items. For example, it is known that the combustion turbine is an incremental cost and is specific to one level of performance.

The configuration also has a significant impact on costs. In addition to the base scaling, adjustments must be made for considerations such as number of trains for a particular system and equipment redundancy (i.e., 2 x 100 percent versus 3 x 50 percent).

The plant location is another issue that must be kept in mind when scaling costs. Project location and labor basis can have a significant impact on overall project costs. An additional adjustment to the labor component may be required to reflect local wage rates, local labor productivity, and a union versus non-union environment.

It is imperative that the reader understand that even subtle differences in equipment specifications can result in significant cost impacts. Adjustments, often in the form of additions or deductions, must be incorporated to address these elements. These could include items such as unique site considerations (piles, access requirements, salt water environment), or specific equipment requirements (stack height, re-heat versus non re-heat, single pressure versus multiple pressure, turbine backpressure).

Finally, the cost basis date must be considered. Equipment, material, and labor costs may need to be escalated or de-escalated to adjust for the differences between the cost basis date for the scaled estimate and the reference estimate. Additionally, significant elapsed time between the reference cost date and the desired date for the scaled estimate could potentially encompass technology or approach changes for a specific item and/or system.

The scaling methodology reported here is specifically developed from and intended for use with December 2018 cost data.

In general, the approach presented in this report is valid for high-level evaluation only. The accuracy of the factored estimate will be less than or equal to that for a reference estimate.

2.2 Methodology

When developing a cost estimate for a plant that requires scaled costing, determine the category type from the category matrix in Exhibit 2-1 that exhibits as much commonality as possible when compared to the plant of interest. Once the category type has been determined, an estimate for a plant of the same type must be obtained for use as a reference. A listing of reports containing example reference cost estimates for each category type is provided in Exhibit 2-2. Reference cost estimates may also be found on the NETL Energy Analysis website.[1]

If the plant of interest does not match any of the available reference cost estimates, select one that most suitably matches, taking care to minimize the impact from the limitations of the scaling approach detailed in Section 3.

For plants of interest that differ significantly from any available reference cost estimates, the plant of interest may still have many of the same subsystems as one or more of the reference cost

[1] http://www.netl.doe.gov/research/energy-analysis

estimates. If so, then the reference cost estimate used may be a combination of various individual reference cost estimates, matched based on subaccount.

Using the category type obtained from the category matrix, utilize Exhibit 3-2 through Exhibit 3-40 to obtain the scaling parameters, exponents, and coefficients. The scaling parameter values associated with the reference cost estimate will be taken from the report from which the reference cost estimate was obtained.

Determine the scaling parameter values for the plant of interest and compare them to the range of applicability provided in Exhibit 3-2 through Exhibit 3-40. If the value is outside the recommended range, significant deviation from realistic results could occur. Given that this guidance is only currently applicable to a small set of published cases, the ranges presented are small and scaling parameter values may be outside the ranges. It is expected that the ranges, in reality, would be capable of being applied to the median range ± 25 percent.

Once the scaling parameters, exponents, and coefficients as well as the reference cost and scaling parameter values are obtained, the scaled cost estimate can be developed by utilizing the equations provided in Section 2.3. Specific guidelines are available in subsections, as follows:

- Section 3.1 PC
- Section 3.2 IGCC
- Section 3.3 NGCC

The following subsection provides an example for developing cost estimates.

2.3 Scaled Cost Estimate Development Examples

The cost estimate development example shown in this section is identical to the example shown in prior versions of this QGESS report. [2] This example was maintained to demonstrate the initial comparison of subaccount matches.

The plant of interest:

The plant of interest in this example is an oxygen-blown two-stage slurry feed gasifier, firing Powder River Basin (PRB) coal at ISO elevation. The plant is equipped with CO_2 capture and compression systems and utilizes a wet cooling tower.

Category type:

Category 7 from the legacy QGESS category matrix [2] most suitably matches the plant of interest as it shares the following items in common:

1. Two-stage slurry feed gasifier
2. Oxygen-blown
3. CO_2 capture
4. PRB coal

Reference plant:

No exact match is available for a ‘reference plant’ as a comparison to the ‘plant of interest.’ Therefore, the ‘reference plant’ will have to be a combination of various ‘reference plants’ based on subaccount matches. The reference plants selected are Case S4B from the Category 7 report

"Cost and Performance Baseline for Fossil Energy Plants - Volume 3a: Low Rank Coal to Electricity: IGCC Cases" [3] and Case 4 from a legacy version of the Category 8 report, *"Cost and Performance Baseline for Fossil Energy Plants, Volume 1b: Bituminous Coal (IGCC) to Electricity Revision 2b - Year Dollar Update."* [4]

Case 4 matches:

1. Cooling type
2. Elevation
3. CO_2 capture
4. Gasifier type

Case S4B matches:

1. Coal type
2. CO_2 capture
3. Gasifier type

It was decided that all accounts that have direct influence from coal will be scaled using Case S4B. All other accounts will be scaled using Case 4.

Accounts scaled using Case S4B include:

1. Coal and Sorbent Handling
2. Coal and Sorbent Preparation and Feed
4. Gasifier and Accessories
5A. Gas Cleanup and Piping
6. Combustion Turbine and Accessories

The account that will be utilized in the example will be Account 5A "Gas Cleanup and Piping."

Obtain Scaling Parameters

Exhibit 3-21 from the legacy QGESS [2] contains the scaling parameters, exponents, coefficients, and ranges for Account 5A of the selected Category 7 plant type.

Exhibit 2-3 provides the account number, item description, scaling parameter, exponent and coefficient, range of applicability, reference parameter value, reference cost, and scaling parameter values that were obtained from the legacy QGESS for Case S4B Category 7. [2]

Exhibit 2-3. Example Account 5A: parameter listing

Account Number	Item Description	Parameter[A]	Exponent [Coefficient][A]	Range[A]	Reference Parameter[B]	Case S4B Reference Costs in June 2007 1000$ (Equipment/TPC)[B]	Scaling Parameter[C]
5A.1	Selexol (Double)	Gas flow to AGR, acfm	0.79	5,000–30,000	11,389	$73,047/$210,112	12,068
5A.2	Elemental Sulfur Plant	Sulfur Production, lb/hr	0.67	200–44,000	4,901	$5,613/$18,396	5,339
5A.3	Mercury Removal	Hg bed carbon fill, ft^3	See Note[D]	2,000–35,000	N/A	$1,328/$3,218	3,916
5A.4	Shift Reactors	WGS Catalyst volume, ft^3	0.80	1,000–11,000	6,257	$8,762/$16,160	6,692
5A.6	Blowback Gas Systems	Candle filter flow rate, acfm	0.30	2,000–96,000	24,282	$2,030/$3,368	26,838
5A.7	Fuel Gas Piping	Fuel gas flow, lb/hr	0.72	185,000–2,490,000	202,347	$0/$1,747	221,487
5A.9	HGCU Foundations	Sulfur Production, lb/hr	0.79	200–44,000	4,901	$0/$1,853	5,339

[A]Information from exhibits in the legacy QGESS [2]
[B]Information from the 'reference' plant report
[C]Scaling parameter from the 'plant of interest'
[D]The exponent 1.57 is used with PRB coal, the exponent 1.64 is used with Illinois No. 6 coal without CO_2 capture, and the exponent 1.59 is used with Illinois No. 6 coal with CO_2 capture. The coefficient 0.0141 is used with all instances.

Calculating scaled cost estimates

Unless otherwise specified, calculating the material cost, labor costs, and equipment cost differs only in the value used as the reference plants reference cost (RC). When calculating the scaled plant's equipment cost, one should use the reference plant's equipment cost as the reference cost; likewise, when calculating the scaled plant's material cost, one should use the reference plant's material cost as the reference cost, etc. The sum of these costs is the bare erected cost (BEC).

The process contingency, project contingency, engineering construction management, home office, and fee are based on a percentage of the BEC. These percentages can be calculated by using Equation 2:

$$SCon = \frac{RCon}{RBEC} \qquad \text{Equation 2}$$

Where:

SCon – Scaled plant's contingency, %

RCon – Reference plant's contingency, $

RBEC – Reference plant's BEC, $

The scaled plant's contingency percentage is multiplied by the scaled plant's BEC to get the scaled plant's contingency dollar value. The process is repeated for each of the individual contingencies.

The sum of the BEC and the contingencies is the total plant cost (TPC) for each sub-account.

The example calculations will focus on determining a scaled Equipment Cost for each subaccount. As such, subaccounts 5A.7 and 5A.9 will not be demonstrated, as their equipment reference value is $0.

By comparing the scaling parameter to the range of applicability, it is confirmed that it is suitable to develop a scaled cost estimate for the plant of interest using the scaling parameters, exponents, and coefficients obtained from the legacy QGESS document. [2]

For all categories, unless otherwise specified, Equation 3 is used to scale costs.

$$SC = RC * \left(\frac{SP}{RP}\right)^{Exp} \qquad \text{Equation 3}$$

Where:

Exp – Exponent

RC– Reference cost

RP – Reference parameter

SC – Scaled cost

SP – Scaling parameter

For this example calculation, IGCC categories that utilize a coefficient in addition to an exponent use Equation 4.

$$SC = \frac{RC}{RTPC} * C * SP^{Exp}$$ Equation 4

Where:

C – Coefficient

Exp – Exponent

RC– Reference cost

RTPC – Reference total plant cost for subaccount

SC – Scaled cost

SP – Scaling parameter

Account 5A.1 will use Equation 3 with the parameter "Gas flow to AGR" in actual ft^3/min. The equation is as follows:

$$SC = \$76{,}466 = \$73{,}047 * \left(\frac{12{,}068 \frac{ft^3}{min}}{11{,}389 \frac{ft^3}{min}} \right)^{0.79}$$ Example 1

Based on the note for Account 5A.3, it contains a coefficient. Therefore, this account will use Equation 4 with the parameter "Hg bed carbon fill" in ft^3. The equation is as follows:

$$SC = \$2{,}544 = \frac{\$1{,}328}{\$3{,}218} * 0.0141 * 3{,}916 ft^{3\,1.57}$$ Example 2

All other subaccounts will use Equation 3. Exhibit 2-4 provides the results of the calculations and compares them to the reference value.

Exhibit 2-4. Example Account 5A: parameter listing

Account Number	Item Description	Parameter	Reference Parameter	Reference Cost (Equipment)	Scaling Parameter	Scaled Cost (Equipment)
5A.1	Selexol (Double)	Gas flow to AGR, acfm	11,389	$73,047	12,068	$76,466
5A.2	Elemental Sulfur Plant	Sulfur Production, lb/hr	4,901	$5,613	5,339	$5,944
5A.3	Mercury Removal	Hg bed carbon fill, ft^3	N/A	$1,328	3,916	$2,544
5A.4	Shift Reactors	WGS Catalyst volume, ft^3	6,257	$8,762	6,692	$9,246
5A.6	Blowback Gas Systems	Candle filter flow rate, acfm	24,282	$2,030	26,838	$2,092

3 Scaling Exponents and Equations

In all instances, the range is intended to present the reader with the ranges at which the exponents have already been utilized. It is expected that the ranges, in reality, would be capable of being applied to the median range ± 25 percent.

For all categories, unless otherwise specified, Equation 5 is used to scale costs.

$$SC = RC * \left(\frac{SP}{RP}\right)^{Exp} \quad \text{Equation 5}$$

Where:

Exp – Exponent

RC– Reference cost

RP – Reference parameter

SC – Scaled cost

SP – Scaling parameter

3.1 PC

Exhibit 3-1 provides the category matrix for the PC categories.

Exhibit 3-1. Category matrix: PC

Category	Technologies
PC	
1	Supercritical[A] PC, air-fired, with and without CO_2 capture, Illinois No. 6 coal
2	Subcritical PC, air-fired, with and without CO_2 capture, Illinois No. 6 coal

[A]In prior versions of this guidance document, ultra-supercritical (USC) PC plants were also included in this category, with the following direction: apply 10-percent process contingency to the line item PC Boiler & Accessories (Account 4.9), and a 15-percent process contingency to the line item Steam Turbine Generator & Accessories (Account 8.1). USC plants could be included in this category using the provided guidance for Revision 4 cases, but NETL reports have not publicly demonstrated application of this guidance to Revision 4 cases to date.

Exhibit 3-2 through Exhibit 3-14 contains the scaling parameters and exponents that are suitable for PC plants at the given ranges.

Exhibit 3-2. Scaling parameters and exponents for categories 1-2: "Coal and Sorbent Handling"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
1	COAL & SORBENT HANDLING				
1.1	Coal Receive & Unload	Coal Feed Rate, lb/hr	0.62	0.62	472,000–635,000
1.2	Coal Stackout & Reclaim	Coal Feed Rate, lb/hr	0.62	0.62	472,000–635,000
1.3	Coal Conveyors & Yard Crushing	Coal Feed Rate, lb/hr	0.62	0.62	472,000–635,000
1.4	Other Coal Handling	Coal Feed Rate, lb/hr	0.62	0.62	472,000–635,000
1.5	Sorbent Receive & Unload	Limestone Feed Rate, lb/hr	0.66	0.62	45,600–61,400
1.6	Sorbent Stackout & Reclaim	Limestone Feed Rate, lb/hr	0.64	0.64	45,600–61,400
1.7	Sorbent Conveyors	Limestone Feed Rate, lb/hr	0.65	0.64	45,600–61,400
1.8	Other Sorbent Handling	Limestone Feed Rate, lb/hr	0.64	0.64	45,600–61,400
1.9	Coal & Sorbent Handling Foundations	Coal and Limestone Feed Rate, lb/hr	0.62	0.62	517,700–695,800

Exhibit 3-3. Scaling parameters and exponents for categories 1-2: "Coal and Sorbent Preparation and Feed"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
2	COAL & SORBENT PREPARATION & FEED				
2.1	Coal Crushing & Drying	Coal Feed Rate, lb/hr	0.66	0.66	472,000–635,000
2.2	Prepared Coal Storage & Feed	Coal Feed Rate, lb/hr	0.66	0.66	472,000–635,000
2.5	Sorbent Preparation Equipment	Limestone Feed Rate, lb/hr	0.65	0.65	45,600–61,400
2.6	Sorbent Storage & Feed	Limestone Feed Rate, lb/hr	0.65	0.65	45,600–61,400
2.9	Coal & Sorbent Feed Foundation	Coal and Limestone Feed Rate, lb/hr	0.64	0.64	517,700–695,800

Exhibit 3-4. Scaling parameters and exponents for categories 1-2: "Feedwater and Miscellaneous BOP Systems"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
3	FEEDWATER & MISCELLANEOUS BOP SYSTEMS				
3.1	Feedwater System	Feedwater Flow (HP Only), lb/hr	0.69	0.68	4,120,000–5,317,000
3.2	Water Makeup & Pretreating	Raw Water Withdrawal, gpm	0.73	0.75	6,000–10,700
3.3	Other Feedwater Subsystems	Feedwater Flow (HP Only), lb/hr	0.89	0.89	4,120,000–5,317,000
3.4	Service Water Systems	Raw Water Withdrawal, gpm	0.80	0.80	6,000–10,700
3.5	Other Boiler Plant Systems	Feedwater Flow (HP Only), lb/hr	0.90	0.90	4,120,000–5,317,000
3.6	Natural Gas Pipeline and Start-up System	Total Fuel Feed, lb/hr	0.49	0.51	472,000–635,000
3.7	Waste Water Treatment Equipment	Process Water Discharge, gpm	0.71	0.73	1,200–3,100
3.8	Spray Dryer Evaporator	Gas Flow to SDE, acfm	0.75	0.75	123,000–166,000
3.9	Miscellaneous Plant Equipment	Total Fuel Feed, lb/hr	0.25	0.25	472,000–635,000

Exhibit 3-5. Scaling parameters and exponents for categories 1-2: "Pulverized Coal Boiler and Accessories"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
4	PULVERIZED COAL BOILER & ACCESSORIES				
4.9	PC Boiler & Accessories (Air-Fired[A])	Feedwater Flow (HP Only), lb/hr	0.76	0.78	4,120,000–5,317,000
4.10	SCR System	Gas Flow to DSI, acfm	0.69		2,489,900–3,346,700
4.11	Boiler Balance of Plant	Coal Feed Rate, lb/hr	0.69		472,000–635,000
4.12	Primary Air System	Primary Air Flow Rate, acfm	0.69		249,300–335,200
4.13	Secondary Air System	Forced Draft Air Flow Rate, acfm	0.69		811,700–1,091,100
4.14	Induced Draft Fans	Gas Flow from Baghouse, acfm	0.69		1,717,500–2,308,500
4.15	Major Component Rigging	Coal Feed Rate, lb/hr	0.69		472,000–635,000
4.16	Boiler Foundations	Coal Feed Rate, lb/hr	0.69		472,000–635,000

[A]Prior versions of this guidance also included circulating fluidized bed combustion (CFBC), oxy-fired PC, and PC with biomass case guidance. These cases have not been developed to date using the Revision 4 cases as a basis, and therefore, no guidance is currently available for these cases.

Exhibit 3-6. Scaling parameters and exponents for categories 1-2: "Flue Gas Cleanup"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
5	FLUE GAS CLEANUP				
5.1	Cansolv CO_2 Removal System	CO_2 Product Flow Rate, lb/hr/ Inlet to Absorber, acfm	0.60[A]		1,281,000–1,348,000/ 1,865,000–1,962,000
5.2	Wet FGD Absorber Vessels & Accessories	Wet FGD Exit Gas Flow, acfm	0.73		1,459,000–1,962,000
5.3	Other FGD	Wet FGD Exit Gas Flow, acfm	0.73		1,459,000–1,962,000
5.4	CO_2 Compression & Drying	Compressor Auxiliary Load, kW[B]	0.61		17,000–46,700
5.5	CO_2 Compressor Aftercooler	Heat Exchanger Duty, MMBtu/hr	0.83		32–88
5.6	Mercury Removal (DSI/ACI)	Brominated Activated Carbon Injection Rate, lb/hr	0.78	0.80	100–140
5.9	Particulate Removal (Bag House & Accessories)	Gas Flow to Baghouse, acfm	0.79		1.691.000–2,274,000
5.12	Gas Cleanup Foundations	Coal Feed Rate, lb/hr	0.79		472,000–635,000
5.13	Gypsum Dewatering System	Gypsum Production Rate, lb/hr	0.58	0.60	69,400–93,300

[A]To scale the Cansolv CO_2 Removal System, 40% of the cost is scaled using the parameter Inlet to Absorber, (acfm); the remaining 60% is scaled using the parameter CO_2 Product Flow Rate (lb/hr).
[B]Compressor Auxiliary Load scaling parameter is valid only for the same suction (28.9 psia) and discharge (2,214.7 psia) pressures assumed in process modeling.

Exhibit 3-7. Scaling parameters and exponents for categories 1-2: "Ductwork and Stack"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
7	DUCTWORK & STACK				
7.3	Ductwork	Total Fuel Feed, lb/hr	0.29		472,000–635,000
7.4	Stack	Gas Flow to Stack, acfm	0.06		1,314,000–1,522,000
7.5	Duct & Stack Foundations	Total Fuel Feed, lb/hr	0.06		472,000–635,000

Exhibit 3-8. Scaling parameters and exponents for categories 1-2: "Steam Turbine & Accessories"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
8	STEAM TURBINE & ACCESSORIES				
8.1	Steam Turbine Generator & Accessories	Steam Turbine Gross Power, MW	0.70		685–776
8.2	Steam Turbine Plant Auxiliaries	Steam Turbine Gross Power, MW	0.70	0.71	685–776
8.3a	Condenser & Auxiliaries	Condenser Duty, MMBtu/hr	1.04	0.86	2,010–2,650
8.3b	Air Cooled Condenser	Condenser Duty, MMBtu/hr	N/A[A]		N/A
8.4	Steam Piping	Feedwater Flow (HP Only), lb/hr	0.70		4,120,000–5,317,000
8.5	Turbine Generator Foundations	Steam Turbine Gross Power, MW	0.71		685–776

[A]Cases from Revision 4 exclusively use wet cooling. Future cases that may use air cooling should insert the Air-Cooled Condenser account here. Guidance on scaling has not yet been developed.

Exhibit 3-9. Scaling parameters and exponents for categories 1-2: "Cooling Water System"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
9	COOLING WATER SYSTEM				
9.1	Cooling Towers	Cooling Tower Duty, MMBtu/hr	0.77	0.76	2,550–4,880
9.2	Circulating Water Pumps	Circulating Water Flow Rate, gpm	0.86		255,000–498,000
9.3	Circ. Water System Auxiliaries	Circulating Water Flow Rate, gpm	0.63		255,000–498,000
9.4	Circ. Water Piping	Circulating Water Flow Rate, gpm	0.63		255,000–498,000
9.5	Make-up Water System	Raw Water Withdrawal, gpm	0.49		6,000–10,700
9.6	Component Cooling Water System	Circulating Water Flow Rate, gpm	0.63		255,000–498,000
9.7	Circ. Water System Foundations	Circulating Water Flow Rate, gpm	0.58		255,000–498,000

Exhibit 3-10. Scaling parameters and exponents for categories 1-2: "Ash and Spent Sorbent Handling Systems"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
10	ASH & SPENT SORBENT HANDLING SYSTEMS				
10.6	Ash Storage Silos	Total Ash Flow Rate, lb/hr	0.56		52,000–70,400
10.7	Ash Transport & Feed Equipment	Total Ash Flow Rate, lb/hr	0.56		52,000–70,400
10.9	Ash/Spent Sorbent Foundation	Total Ash Flow Rate, lb/hr	0.56		52,000–70,400

Exhibit 3-11. Scaling parameters and exponents for categories 1-2: "Accessory Electric Plant"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
11	ACCESSORY ELECTRIC PLANT				
11.1	Generator Equipment	Steam Turbine Gross Power, MW	0.57		685–776
11.2	Station Service Equipment	Auxiliary Load, kW	0.43		35,000–125,800
11.3	Switchgear & Motor Control	Auxiliary Load, kW	0.43		35,000–125,800
11.4	Conduit & Cable Tray	Auxiliary Load, kW	0.43		35,000–125,800
11.5	Wire & Cable	Auxiliary Load, kW	0.43		35,000–125,800
11.6	Protective Equipment	Auxiliary Load, kW	0.00		35,000–125,800
11.7	Standby Equipment	Steam Turbine Gross Power, MW	0.46		685–776
11.8	Main Power Transformers	STG Rating, MVA	0.70		760–860
11.9	Electrical Foundations	Steam Turbine Gross Power, MW	0.69		685–776

Exhibit 3-12. Scaling parameters and exponents for categories 1-2: "Instrumentation & Control"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
12	INSTRUMENTATION & CONTROL				
12.1	PC Boiler Control Equipment	Auxiliary Load, kW	0.13		35,000–125,800
12.3	Steam Turbine Control Equipment	Auxiliary Load, kW	0.13		35,000–125,800
12.5	Signal Processing Equipment	Auxiliary Load, kW	0.13		35,000–125,800
12.6	Control Boards, Panels & Racks	Auxiliary Load, kW	0.13		35,000–125,800
12.7	Distributed Control System Equipment	Auxiliary Load, kW	0.13		35,000–125,800
12.8	Instrument Wiring & Tubing	Auxiliary Load, kW	0.13		35,000–125,800
12.9	Other I&C Equipment	Auxiliary Load, kW	0.13		35,000–125,800

Exhibit 3-13. Scaling parameters and exponents for categories 1-2: "Improvements to Site"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
13	IMPROVEMENTS TO SITE				
13.1	Site Preparation	BEC (Minus Acts. 13 and 14)	0.20		883,600–1,622,000
13.2	Site Improvements	BEC (Minus Acts. 13 and 14)	0.20		883,600–1,622,000
13.3	Site Facilities	BEC (Minus Acts. 13 and 14)	0.20		883,600–1,622,000

Exhibit 3-14. Scaling parameters and exponents for categories 1-2: "Buildings & Structures"

Account Number	Item Description	Parameter	Exponent		Range
Category		1-2	1	2	1-2
14	BUILDINGS & STRUCTURES				
14.2	Boiler Building	BEC (Minus Acts. 13 and 14)	0.00		883,600–1,622,000
14.3	Steam Turbine Building	BEC (Minus Acts. 13 and 14)	0.00		883,600–1,622,000
14.4	Administration Building	Steam Turbine Gross Power, MW	0.00		685–776
14.5	Circulation Water Pumphouse	Circulating Water Flow Rate, gpm	0.60	0.59	255,000–498,000
14.6	Water Treatment Buildings	Raw Water Withdrawal, gpm	0.50		6,000–10,700
14.7	Machine Shop	Steam Turbine Gross Power, MW	0.00		685–776
14.8	Warehouse	Steam Turbine Gross Power, MW	0.00		685–776
14.9	Other Buildings & Structures	Steam Turbine Gross Power, MW	0.00		685–776
14.10	Waste Treating Building & Structures	Raw Water Withdrawal, gpm	0.05		6,000–10,700

3.2 IGCC

Exhibit 3-15 provides the category matrix for IGCC categories.

Exhibit 3-15. Category matrix: IGCC

Category	Technologies
3	Two-stage, slurry-feed, oxygen-blown gasifier with and without CO_2 capture, Illinois No. 6 coal
4	Single-stage, slurry-feed, oxygen-blown gasifier with and without CO_2 capture, Illinois No. 6 coal
5	Single-stage, dry-feed, oxygen-blown, up-flow gasifier with and without CO_2 capture, Illinois No. 6 coal

Exhibit 3-16 through Exhibit 3-29 contain the scaling parameters and exponents that are suitable for IGCC plants at the given ranges.

Exhibit 3-16. Scaling parameters and exponents for categories 3-5: "Coal Handling"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
1	COAL HANDLING					
1.1	Coal Receive & Unload	Coal Feed Rate, lb/hr	0.62			435,000–483,000
1.2	Coal Stackout & Reclaim	Coal Feed Rate, lb/hr	0.62			435,000–483,000
1.3	Coal Conveyors & Yard Crush	Coal Feed Rate, lb/hr	0.62			435,000–483,000
1.4	Other Coal Handling	Coal Feed Rate, lb/hr	0.62			435,000–483,000
1.9	Coal & Sorbent Handling Foundations	Coal Feed Rate, lb/hr	0.62			435,000–483,000

Exhibit 3-17. Scaling parameters and exponents for categories 3-5: "Coal Preparation and Feed"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
2	COAL PREPARATION & FEED					
2.1	Coal Crushing & Drying	Coal Feed Rate, lb/hr	0.66			435,000–483,000
2.2	Prepared Coal Storage & Feed	Coal Feed Rate, lb/hr	0.66			435,000–483,000
2.3	Dry Coal Injection System/ Slurry Coal Injection System	Coal Feed Rate, lb/hr	0.66			435,000–483,000
2.4	Miscellaneous Coal Prep & Feed	Coal Feed Rate, lb/hr	0.66			435,000–483,000
2.9	Coal & Sorbent Feed Foundation	Coal Feed Rate, lb/hr	0.66			435,000–483,000

Exhibit 3-18. Scaling parameters and exponents for categories 3-5: "Feedwater and Miscellaneous BOP Systems"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
3	FEEDWATER & MISCELLANEOUS BOP SYSTEMS					
3.1	Feedwater System	Feedwater Flow (HP only), lb/hr	0.71			839,700–1,597,000
3.2	Water Makeup & Pretreating	Raw Water Withdrawal, gpm	0.71			4,100–6,300
3.3	Other Feedwater Subsystems	Feedwater Flow (HP only), lb/hr	0.71			839,700–1,597,000
3.4	Service Water Systems	Raw Water Withdrawal, gpm	0.71			4,100–6,300
3.5	Other Boiler Plant Systems	Feedwater Flow (HP only), lb/hr	0.73			839,700–1,597,000
3.6	Natural Gas Pipeline and Start-Up System	Coal Feed Rate, lb/hr	0.24			435,000–483,000
3.7	Waste Water Treatment Equipment	Process Water Discharge, gpm	0.71			900–1,220
3.8	Vacuum Flash, Brine Concentrator, & Crystallizer	Syngas Scrubber Blowdown Flow Rate, gpm	0.76			275–635
3.9	Miscellaneous Plant Equipment	Coal Feed Rate, lb/hr	0.24			435,000–483,000

Exhibit 3-19. Scaling parameters and exponents for categories 3-5: "Gasifier, ASU, and Accessories"

Account Number	Item Description	Parameter	Exponent [Coefficient]			Range
Category		3-5	3	4[A]	5	3-5
4	GASIFIER, ASU, & ACCESSORIES					
4.1	Gasifier & Auxiliaries	Coal Feed Rate, lb/hr	0.19	0.70[B] {0.00}[C] See Note[D]	1.42	435,000–483,000 {464,700–482,900} See Note[C]
4.2	Syngas Cooler	Syngas Cooler Duty, MMBtu/hr	0.33	N/A	0.33	110–200
4.3	Air Separation Unit/Oxidant Compression	O_2 Production, TPD/ Main Air Compressor Power, kW	0.70/0.70 [0.50/0.50][E]			4,000–4,800 61,000–71,400
4.5	Miscellaneous Gasification Equipment	Coal Feed Rate, lb/hr	0.50			435,000–483,000
4.6	LT Heat Recovery & Flue Gas Saturation	Coal Feed Rate, lb/hr	See Note[F]			435,000–483,000
4.7	Flare Stack System	Coal Feed Rate, lb/hr	0.50			435,000–483,000
4.8	Black Water & Sour Gas Section	Coal Feed Rate, lb/hr	N/A	See Note[G]	N/A	435,000–483,000
4.15	Major Component Rigging	Coal Feed Rate, lb/hr	0.50			435,000–483,000
4.16	Gasification Foundations	Coal Feed Rate, lb/hr	0.50			435,000–483,000

$$SC = C_1 * RC * \left(\frac{SP_1}{RP_1}\right)^{Exp_1} + C_2 * RC * \left(\frac{SP_2}{RP_2}\right)^{Exp_2}$$ Equation 6

[A]The GE Quench-Only case is not subject to category 4 scaling guidance. Only a single data point for GE Quench-Only is available; thus, no scaling guidance has been developed.
[B]For cases that do not fall into the categories of change in number of trains or small changes within a set gasifier feed rate, scale on Coal Feed Rate (lb/hr) with exponent of 0.70.
[C]Gasifier designs are marketed for a set inlet coal feed rate. It's unclear if gasifier vendors would customize gasifier sizes for individual inlet coal feed rates, or if there would be cost impacts of customization of size. Therefore, for small changes in inlet coal feed rate (18,200 lb/hr [220 tpd]), the gasifier cost should remain unchanged from the reference case, and an exponent of 0.00 should be used.
[D]The category 4 cases consider two parallel gasifier trains. If the change in Coal Feed Rate is significant enough to add or remove a full gasifier train (e.g., +/- 50% in Coal Feed Rate), the Account 4.1 reference case capital cost should be adjusted by multiplying by 1.5 (add one gasifier train), 0.5 (remove one gasifier train), or the appropriate factor reflecting the change in number of gasifier trains.
[E]Use Equation 6.
[F]The ratio of Account 4.6 divided by Account 4.1 should be maintained from the reference case.
[G]Account 4.8 costs are included in Account 4.1; thus, no scaling guidance is provided.

Exhibit 3-20. Scaling parameters and exponents for categories 3-5: "Syngas Cleanup"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
5	SYNGAS CLEANUP					
5.1	Double Stage Selexol	Gas Flow to AGR, acfm	0.79			6,500–14,000
5.2	Sulfur Removal (Sulfinol, MDEA, Single Stage Selexol)	Gas Flow to AGR, acfm	See Note[A]			See Note[A]
5.3	Elemental Sulfur Plant	Sulfur Production, lb/hr	0.67			10,800–12,100
5.4	Carbon Dioxide Compression & Drying	Compressor Auxiliary Load, kW[B]	0.88			17,000–46,700
5.5	Carbon Dioxide Aftercooler	Heat Exchanger Duty, MMBtu/hr	0.83			32–88
5.6	Mercury Removal (Carbon Bed)	Sulfur-Impregnated Activated Carbon Initial Fill, ft^3	1.64			3,400–7,600
5.7	Shift Reactors	WGS Catalyst Initial Fill, ft^3	0.80			9,800–25,800
5.8	COS Hydrolysis	COS Hydrolysis Catalyst Volume, ft^3	0.80			1,300–2,200
5.9	Particulate Removal	Candle Filter Flow Rate, acfm	0.79	N/A	0.79	19,200–29,300
5.10	Blowback Gas Systems	Candle Filter Flow Rate, acfm	0.30			13,700–29,300
5.11	Fuel Gas Piping	Syngas Flow Rate, lb/hr	0.72			182,300–870,300
5.12	Gas Cleanup Foundations	Sulfur Production, lb/hr	0.79			10,800–12,100

[A] Only one data point is available for each of the Sulfur Removal Systems (Sulfinol, MDEA, Single Stage Selexol); therefore, no scaling guidance has been developed. It is recommended that these cases be scaled on Gas Flow to AGR (acfm) with an exponent of 0.70.
[B] Compressor Auxiliary Load scaling parameter is valid only for the same suction and discharge pressures assumed in process modeling, as well as the same compressor configuration compatible with a Double Stage Selexol System.

Exhibit 3-21. Scaling parameters and exponents for categories 3-5: "Combustion Turbine and Accessories"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
6	COMBUSTION TURBINE & ACCESSORIES					
6.1	Combustion Turbine Generator	Syngas Flow Rate, lb/hr	0.00[A]			182,300–870,300
6.2	Syngas Expander	Syngas Flow Rate, lb/hr	N/A	0.88	N/A	182,300–870,300
6.3	Combustion Turbine Accessories	Syngas Flow Rate, lb/hr	0.00			182,300–870,300
6.4	Compressed Air Piping	Syngas Flow Rate, lb/hr	0.00			182,300–870,300
6.5	Combustion Turbine Foundations	Syngas Flow Rate, lb/hr	0.00			182,300–870,300

[A]Combustion Turbine Generator costs are slightly different depending on whether the case includes CO_2 capture, or is non-capture. When scaling this account, only scale capture to capture cases, or non-capture to non-capture cases; do not scale capture to non-capture cases, or vice versa.

Exhibit 3-22. Scaling parameters and exponents for categories 3-5: "HRSG, Ductwork, and Stack"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
7	HRSG, DUCTWORK & STACK					
7.1	Heat Recovery Steam Generator	HRSG Duty, MMBtu/hr	0.70			1,770–1,930
7.2	HRSG Accessories	HRSG Duty, MMBtu/hr	0.70			1,770–1,930
7.3	Ductwork	Gas Flow to Stack, acfm	0.64	0.70	0.70	2,611,000–2,705,000
7.4	Stack	Gas Flow to Stack, acfm	0.70			2,611,000–2,705,000
7.5	HRSG, Ductwork & Stack Foundations	Gas Flow to Stack, acfm	0.70	0.70	0.73	2,611,000–2,705,000

Exhibit 3-23. Scaling parameters and exponents for categories 3-5: "Steam Turbine & Accessories"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
8	STEAM TURBINE & ACCESSORIES					
8.1	Steam Turbine Generator & Accessories	Steam Turbine Gross Power, kW	0.70			217,400–301,200
8.2	Steam Turbine Plant Auxiliaries	Steam Turbine Gross Power, kW	0.71			217,400–301,200
8.3a	Condenser & Auxiliaries	Condenser Duty, MMBtu/hr	0.71			1,275–1,570
8.3b	Air Cooled Condenser	Condenser Duty, MMBtu/hr	N/A[A]			N/A
8.4	Steam Piping	Feedwater Flow (HP only), lb/hr	0.72			839,700–1,597,000
8.5	Turbine Generator Foundations	Steam Turbine Gross Power, kW	0.72			217,400–301,200

[A]Cases from Revision 4 exclusively use wet cooling. Future cases that may use air cooling should insert the Air-Cooled Condenser account here. Guidance on scaling has not yet been developed.

Exhibit 3-24. Scaling parameters and exponents for categories 3-5: "Cooling Water System"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
9	COOLING WATER SYSTEM					
9.1	Cooling Towers	Cooling Tower Duty, MMBtu/hr	0.72			1,920–2,540
9.2	Circulating Water Pumps	Circulating Water Flow Rate, gpm	0.72			192,000–253,700
9.3	Circulating Water System Auxiliaries	Circulating Water Flow Rate, gpm	0.64		0.67	192,000–253,700
9.4	Circulating Water Piping	Circulating Water Flow Rate, gpm	0.61			192,000–253,700
9.5	Make-up Water System	Raw Water Withdrawal, gpm	0.63			4,100–6,300
9.6	Component Cooling Water System	Circulating Water Flow Rate, gpm	0.64			192,000–253,700
9.7	Circulating Water System Foundations	Circulating Water Flow Rate, gpm	0.59			192,000–253,700

Exhibit 3-25. Scaling parameters and exponents for categories 3-5: "Slag Recovery & Handling"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
10	SLAG RECOVERY & HANDLING					
10.1	Slag Dewatering & Cooling	Slag Production, lb/hr	0.64			43,600–53,000
10.2	Gasifier Ash Depressurization	Slag Production, lb/hr	0.64			43,600–53,000
10.3	Cleanup Ash Depressurization	Slag Production, lb/hr	0.64			43,600–53,000
10.6	Ash Storage Silos	Slag Production, lb/hr	0.55			43,600–53,000
10.7	Ash Transport & Feed Equipment	Slag Production, lb/hr	0.55			43,600–53,000
10.8	Miscellaneous Ash Handling Equipment	Slag Production, lb/hr	0.55			43,600–53,000
10.9	Ash/Spent Sorbent Foundation	Slag Production, lb/hr	0.55			43,600–53,000

Exhibit 3-26. Scaling parameters and exponents for categories 3-5: "Accessory Electric Plant"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
11	ACCESSORY ELECTRIC PLANT					
11.1	Generator Equipment	Steam Turbine Gross Power, kW	0.54			217,400–301,200
11.2	Station Service Equipment	Auxiliary Load, kW	0.45			122,400–185,600
11.3	Switchgear & Motor Control	Auxiliary Load, kW	0.45			122,400–185,600
11.4	Conduit & Cable Tray	Auxiliary Load, kW	0.45			122,400–185,600
11.5	Wire & Cable	Auxiliary Load, kW	0.45			122,400–185,600
11.6	Protective Equipment	Auxiliary Load, kW	0.00			122,400–185,600
11.7	Standby Equipment	Total Plant Gross Power, kW	0.48			684,700–765,200
11.8	Main Power Transformers	Total Plant Gross Power, kW	0.71			684,700–765,200
11.9	Electrical Foundations	Total Plant Gross Power, kW	0.70			684,700–765,200

Exhibit 3-27. Scaling parameters and exponents for categories 3-5: "Instrumentation and Control"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
12	INSTRUMENTATION & CONTROL					
12.1	IGCC Control Equipment	Auxiliary load, kW	0.13			122,400–185,600
12.2	Combustion Turbine Control Equipment	Auxiliary load, kW	0.13			122,400–185,600
12.3	Steam Turbine Control Equipment	Auxiliary load, kW	0.13			122,400–185,600
12.4	Other Major Component Control Equipment	Auxiliary load, kW	0.13			122,400–185,600
12.5	Signal Processing Equipment	Auxiliary load, kW	0.13			122,400–185,600
12.6	Control Boards, Panels & Racks	Auxiliary load, kW	0.13			122,400–185,600
12.7	Distributed Control System Equipment	Auxiliary load, kW	0.13			122,400–185,600
12.8	Instrument Wiring & Tubing	Auxiliary load, kW	0.13			122,400–185,600
12.9	Other I&C Equipment	Auxiliary load, kW	0.13			122,400–185,600

Exhibit 3-28. Scaling parameters and exponents for categories 3-5: "Improvements to Site"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
13	IMPROVEMENTS TO SITE					
13.1	Site Preparation	BEC (Minus Acts. 13 and 14)	0.08			1,494,000–2,188,000
13.2	Site Improvements	BEC (Minus Acts. 13 and 14)	0.08			1,494,000–2,188,000
13.3	Site Facilities	BEC (Minus Acts. 13 and 14)	0.08			1,494,000–2,188,000

Exhibit 3-29. Scaling parameters and exponents for categories 3-5: "Buildings and Structures"

Account Number	Item Description	Parameter	Exponent			Range
Category		3-5	3	4	5	3-5
14	BUILDINGS & STRUCTURES					
14.1	Combustion Turbine Area	Combustion Turbine Gross Power, kW	0.00			348,000–580,000
14.3	Steam Turbine Building	Steam Turbine Gross Power, kW	0.06			217,400–301,200
14.4	Administration Building	Steam Turbine Gross Power, kW	0.04			217,400–301,200
14.5	Circulation Water Pumphouse	Circulating Water Flow Rate, gpm	0.46			192,000–253,700
14.6	Water Treatment Buildings	Raw Water Withdrawal, gpm	0.71			4,100–6,300
14.7	Machine Shop	Steam Turbine Gross Power, kW	0.02			217,400–301,200
14.8	Warehouse	Steam Turbine Gross Power, kW	0.02			217,400–301,200
14.9	Other Buildings & Structures	Steam Turbine Gross Power, kW	0.02			217,400–301,200
14.10	Waste Treating Building & Structures	Raw Water Withdrawal, gpm	0.09			4,100–6,300

3.3 NGCC

Exhibit 3-30 provides the category matrix for NGCC categories.

Exhibit 3-30. Category matrix: NGCC

Category	Technologies
6	Natural gas, air-fired, with and without CO_2 capture

Exhibit 3-31 through Exhibit 3-40 contain the scaling parameters and exponents that are suitable for NGCC plants at the given ranges.

Exhibit 3-31. Scaling parameters and exponents for categories 6: "Feedwater and Miscellaneous BOP Systems"

Account Number	Item Description	Parameter	Exponent	Range
	Category	6	6	6
3	FEEDWATER & MISCELLANEOUS BOP SYSTEMS			
3.1	Feedwater System	Feedwater Flow (HP only), lb/hr	0.72	803,200–1,339,000
3.2	Water Makeup & Pretreating	Raw Water Withdrawal, gpm	0.73	2,900–4,700
3.3	Other Feedwater Subsystems	Feedwater Flow (HP only), lb/hr	0.72	803,200–1,339,000
3.4	Service Water Systems	Raw Water Withdrawal, gpm	0.73	2,900–4,700
3.5	Other Boiler Plant Systems	Raw Water Withdrawal, gpm	0.00	N/A[A]
3.6	Natural Gas Pipeline and Start-Up System	Fuel Gas Flow, acfm average	0.00[B]	N/A[B]
3.7	Waste Water Treatment Equipment	Process Water Discharge, gpm	0.71	650–1,670
3.9	Miscellaneous Plant Equipment	Fuel Gas Flow, acfm average	0.00	N/AB

[A]Combustion turbines are manufactured in discrete sizes. As such, certain cost accounts become fixed costs for a given combustion turbine size. For example, the Acct. 3.6 Natural Gas Pipeline cost will be identical for a common combustion turbine output, and, therefore, common natural gas feed flow rate. Thus, no scaling range is provided.
[B]As noted in the item description, this line item also includes the natural gas pipeline. The natural gas pipeline is an additive cost and would not be scaled. The pipeline cost is specific to the plant location and needs. Scaling over larger ranges will result in unrealistic costs since this has the effect of essentially increasing and decreasing the pipe length. If alternate fuel gas flow rates are required, a more detailed build-up of the natural gas pipeline cost is recommended.

Exhibit 3-32. Scaling parameters and exponents for categories 6: "Flue Gas Cleanup"

Account Number	Item Description	Parameter	Exponent	Range
Category		6	6	6
5B	FLUE GAS CLEANUP			
5.1	Cansolv CO_2 Removal System	CO_2 Product Flow Rate, lb/hr/Inlet to Absorber, acfm	0.60[A]	370,000–617,000/ 1,915,000–3,192,000
5.4	CO_2 Compression & Drying	Compressor Auxiliary Load, kW[B]	0.41	17,000–46,700
5.5	CO_2 Compressor Aftercooler	Heat Exchanger Duty, MMBtu/hr	0.83	32–88
5.12	Gas Cleanup Foundations	CO_2 Flow Rate, lb/hr	0.79	370,000–617,000

[A]To scale the Cansolv CO_2 Removal System, 40% of the cost is scaled using the parameter Inlet to Absorber, (acfm); the remaining 60% is scaled using the parameter CO_2 Product Flow Rate (lb/hr).
[B]Compressor Auxiliary Load scaling parameter is valid only for the same suction (28.9 psia) and discharge (2,214.7 psia) pressures assumed in process modeling.

Exhibit 3-33. Scaling parameters and exponents for categories 6: "Combustion Turbine and Accessories"

Account Number	Item Description	Parameter	Exponent	Range
Category		6	6	6
6	COMBUSTION TURBINE & ACCESSORIES[A]			
6.1	Combustion Turbine Generator	Fuel Gas Flow, acfm	0.00	N/A
6.3	Combustion Turbine Accessories	Fuel Gas Flow, acfm	0.00	N/A
6.4	Compressed Air Piping	Fuel Gas Flow, acfm	0.00	N/A
6.5	Combustion Turbine Foundations	Combustion Turbine Gross Power, kW	0.00	N/A

[A]Combustion turbines are manufactured in discrete sizes. As such, certain cost accounts become fixed costs for a given combustion turbine size. Thus, no scaling range is provided, and all exponents are shown as 0.00.

Exhibit 3-34. Scaling parameters and exponents for categories 6: "HRSG, Ductwork, and Stack"

Account Number	Item Description	Parameter	Exponent	Range
Category		6	6	6
7	HRSG, DUCTWORK, & STACK			
7.1	Heat Recovery Steam Generator	HRSG Duty, MMBtu/hr	0.70	1,950–2,300
7.2	HRSG Accessories	HRSG Duty, MMBtu/hr	1.40	1,950–2,300
7.3	Ductwork	Gas Flow to Stack, acfm	0.70	1,833,000–2,365,000
7.4	Stack	Gas Flow to Stack, acfm	0.70	1,833,000–2,365,000
7.5	HRSG Ductwork & Stack Foundations	Gas Flow to Stack, acfm	0.70	1,833,000–2,365,000
7.6	Selective Catalytic Reduction System	Flue Gas Flow to HRSG, acfm	0.00[A]	N/A

[A]Combustion turbines are manufactured in discrete sizes. As such, certain cost accounts become fixed costs for a given combustion turbine size. In the case of SCR, flue gas flow rate is identical between NGCC with and without CO_2 capture cases; in the case of Steam Piping, HP steam flow rate is identical between the two NGCC cases; thus, no scaling range is provided, and the exponent is 0.00.

Exhibit 3-35. Scaling parameters and exponents for categories 6: "Steam Turbine and Accessories"

Account Number	Item Description	Parameter	Exponent	Range
Category		6	6	6
8	STEAM TURBINE & ACCESSORIES			
8.1	Steam Turbine Generator & Accessories	Steam Turbine Gross Power, kW	0.80	212,500–263,000
8.2	Steam Turbine Plant Auxiliaries	Steam Turbine Gross Power, kW	0.73	212,500–263,000
8.3	Condenser & Auxiliaries	Condenser Duty, MMBtu/hr	0.80	788–1,340
8.4	Steam Piping	Feedwater Flow (HP only), lb/hr	0.00[A]	803,200–1,339,000
8.5	Turbine Generator Foundations	Steam Turbine Gross Power, kW	0.73	212,500–263,000

[A]Combustion turbines are manufactured in discrete sizes. As such, certain cost accounts become fixed costs for a given combustion turbine size. In the case of SCR, flue gas flow rate is identical between NGCC with and without CO_2 capture cases; in the case of Steam Piping, HP steam flow rate is identical between the two NGCC cases; thus, no scaling range is provided, and the exponent is 0.00.

Exhibit 3-36. Scaling parameters and exponents for categories 6: "Cooling Water System"

Account Number	Item Description	Parameter	Exponent	Range
Category		6	6	6
9	COOLING WATER SYSTEM			
9.1	Cooling Towers	Cooling Tower Duty, MMBtu/hr	0.73	1,300–2,200
9.2	Circulating Water Pumps	Circulating Water Flow Rate, gpm	0.72	135,700–220,800
9.3	Circ. Water System Auxiliaries	Circulating Water Flow Rate, gpm	0.49	135,700–220,800
9.4	Circ. Water Piping	Circulating Water Flow Rate, gpm	0.60	135,700–220,800
9.5	Make-up Water System	Raw Water Withdrawal, gpm	0.40	2,900–4,700
9.6	Component Cooling Water System	Circulating Water Flow Rate, gpm	0.60	135,700–220,800
9.7	Circ. Water System Foundations	Circulating Water Flow Rate, gpm	0.60	135,700–220,800

Exhibit 3-37. Scaling parameters and exponents for categories 6: "Accessory Electric Plant"

Account Number	Item Description	Parameter	Exponent	Range
Category		6	6	6
11	ACCESSORY ELECTRIC PLANT			
11.1	Generator Equipment	Total Plant Gross Power, kW	0.59	689,800–740,100
11.2	Station Service Equipment	Auxiliary Load, kW	0.64	13,500–44,000
11.3	Switchgear & Motor Control	Auxiliary Load, kW	0.64	13,500–44,000
11.4	Conduit & Cable Tray	Auxiliary Load, kW	0.64	13,500–44,000
11.5	Wire & Cable	Auxiliary Load, kW	0.64	13,500–44,000
11.6	Protective Equipment	Auxiliary Load, kW	1.10	13,500–44,000
11.7	Standby Equipment	Total Plant Gross Power, kW	0.48	689,800–740,100
11.8	Main Power Transformers	STG output, MVA PLUS CTG output, MVA	1.36	520–580
11.9	Electrical Foundations	Total Plant Gross Power, kW	0.70	689,800–740,100

Exhibit 3-38. Scaling parameters and exponents for categories 6: "Instrumentation and Control"

Account Number	Item Description	Parameter	Exponent	Range
Category		6	6	6
12	INSTRUMENTATION & CONTROL			
12.1	NGCC Control Equipment	Auxiliary Load, kW	0.13	13,500–44,000
12.2	Combustion Turbine Control Equipment	Auxiliary Load, kW	0.00	13,500–44,000
12.3	Steam Turbine Control Equipment	Auxiliary Load, kW	0.13	13,500–44,000
12.4	Other Major Component Control Equipment	Auxiliary Load, kW	0.16	13,500–44,000
12.5	Signal Processing Equipment	Auxiliary Load, kW	0.13	13,500–44,000
12.6	Control Boards, Panels & Racks	Auxiliary Load, kW	0.16	13,500–44,000
12.7	Distributed Control System Equipment	Auxiliary Load, kW	0.16	13,500–44,000
12.8	Instrument Wiring & Tubing	Auxiliary Load, kW	0.16	13,500–44,000
12.9	Other I&C Equipment	Auxiliary Load, kW	0.16	13,500–44,000

Exhibit 3-39. Scaling parameters and exponents for categories 6: "Improvements to Site"

Account Number	Item Description	Parameter	Exponent	Range
Category		6	6	6
13	IMPROVEMENTS TO SITE			
13.1	Site Preparation	Total Plant Gross Power, kW	0.46	689,800–740,100
13.2	Site Improvements	Total Plant Gross Power, kW	0.46	689,800–740,100
13.3	Site Facilities	Total Plant Gross Power, kW	0.46	689,800–740,100

Exhibit 3-40. Scaling parameters and exponents for categories 6: "Buildings and Structures"

Account Number	Item Description	Parameter	Exponent	Range
Category		6	6	6
14	BUILDINGS & STRUCTURES			
14.1	Combustion Turbine Area	Gas Turbine Power, kW	0.00[A]	N/A
14.3	Steam Turbine Building	Steam Turbine Gross Power, kW	0.60	212,500–263,000
14.4	Administration Building	Total Plant Gross Power, kW	0.35	689,800–740,100
14.5	Circulation Water Pumphouse	Circulating Water Flow Rate, gpm	0.82	135,700–220,800
14.6	Water Treatment Buildings	Raw Water Withdrawal, gpm	0.66	2,900–4,700
14.7	Machine Shop	Total Plant Gross Power, kW	0.36	689,800–740,100
14.8	Warehouse	Total Plant Gross Power, kW	0.34	689,800–740,100
14.9	Other Buildings & Structures	Total Plant Gross Power, kW	0.25	689,800–740,100
14.10	Waste Treating Building & Structures	Total Plant Gross Power, kW	0.34	689,800–740,100

[A]Combustion turbines are manufactured in discrete sizes. As such, certain cost accounts become fixed costs for a given combustion turbine size. Thus, no scaling range is provided, and the exponent is 0.00.

4 Revision Control

Exhibit 4-1. Revision table

Revision Number	Revision Date	Description of Change	Comments
1	February 5, 2014	Document formatted and edited.	
2	March 2, 2016	Methodology validated for June 2011 data reported in revisions 2a and 2b of the Bituminous Baseline. Values edited where necessary.	
3 – Revision 3 Reports and Prior	April 9, 2016	Parameters, exponents, and ranges were compared against similar internal categories within this document, and against the Aspen performance template results for Revision 3 cases. Adjustments were made as necessary. Document was also formatted.	
3 – Revision 4 Report	October 3, 2019	Incorporated Revision 4 updates.	

5 References

[1] National Energy Technology Laboratory (NETL), "Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity Revision 4," Pittsburgh, PA, 2019.

[2] National Energy Technology Laboratory (NETL), "Quality Guidelines for Energy System Studies: Capital Cost Scaling Methodology: Revision 3 Reports and Prior," Pittsburgh, PA, 2019.

[3] National Energy Technology Laboratory (NETL), "Cost and Performance Baseline for Fossil Energy Plants Volume 3a: Low Rank Coal to Electricity: IGCC Cases," Pittsburgh, PA, 2011.

[4] National Energy Technology Laboratory (NETL), "Cost and Performance Baseline for Fossil Energy Plants Volume 1b: Bituminous Coal (IGCC) to Electricity Revision 2b - Year Dollar Update," PIttsburgh, PA, 2015.