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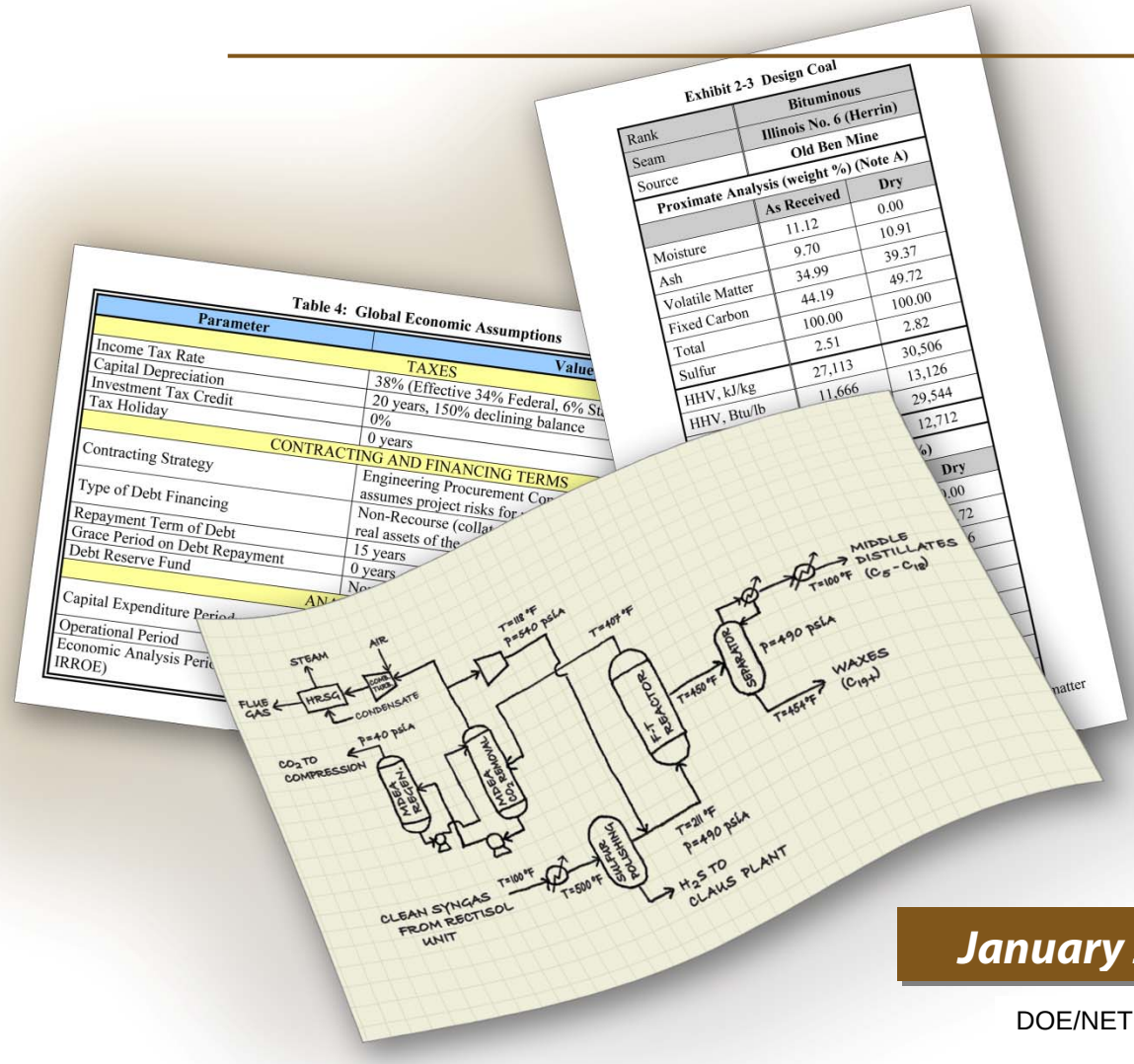
QUALITY GUIDELINES FOR ENERGY SYSTEM STUDIES

Capital Cost Scaling Methodology



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Quality Guidelines for Energy Systems Studies
Capital Cost Scaling Methodology

Final Report

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NETL Contact:

James Black
General Engineer
Office of Program Planning & Analysis, Performance Division

National Energy Technology Laboratory
www.netl.doe.gov

Prepared by:

Energy Sector Planning and Analysis (ESPA)

Marc J. Turner
Booz Allen Hamilton, Inc.

Reviewed by:

Lora L. Pinkerton
WorleyParsons Group, Inc.

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1 Introduction

Costs are frequently required as part of systems analysis work at the National Energy Technology Laboratory (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, etc.) 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 Quality Guidelines 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.

Equation 1

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

Where:

- Exp – Exponent
- RC – Reference Cost
- RP – Reference Parameter

Exhibit 1-1 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 1-2 provides a listing of reference reports for the various categories.

The listings are divided into three major technologies frequently analyzed at NETL: combustion [pulverized coal (PC) and circulating fluidized bed combustion (CFBC)]; integrated gasification combined cycle (IGCC); and natural gas combined cycle (NGCC).

Exhibit 1-1 Category matrix

Category	Technologies
PC/CFBC	
1	Supercritical PC, air-fired, with and without CO_2 capture, Illinois #6 coal with hybrid poplar
	Supercritical PC, oxy-fired, with CO_2 capture, Illinois #6 coal with hybrid poplar
	Supercritical and ultra-supercritical[1] PC, oxy-fired, with CO_2 capture, Illinois #6 coal
2	CFBC, air-fired, with and without CO_2 capture, PRB and ND Lignite coals
	CFBC, oxy-fired, with CO_2 capture, PRB and ND Lignite coals
3	Supercritical PC, air-fired, with and without CO_2 capture, ND lignite and PRB coals
	Ultra-supercritical PC[1], air-fired, with and without CO_2 capture, ND lignite and PRB coals
	Supercritical PC, oxy-fired, with CO_2 capture, ND lignite and PRB coals
	Ultra-supercritical PC[1], oxy-fired, with CO_2 capture, ND lignite and PRB coals
4	Supercritical and ultra-supercritical PC[1], air-fired, with and without CO_2 capture, Illinois #6 coal
5	Subcritical PC, air-fired, with and without CO_2 capture, Illinois #6 coal
IGCC	
6	Single-stage, dry-feed, oxygen-blown, down-flow gasifier with and without CO_2 capture, PRB and ND lignite coals
7	Two-stage, slurry-feed, oxygen-blown gasifier with and without CO_2 capture, PRB coal
	Single-stage, slurry-feed, oxygen-blown gasifier with and without CO_2 capture, Illinois #6 coal
8	Single-stage, dry-feed, oxygen-blown, up-flow gasifier,with CO_2 capture, PRB coal with and without switchgrass
	Single-stage, dry-feed, oxygen-blown, up-flow gasifier with CO_2 capture, Illinois #6 coal with switchgrass
	Single-stage, dry-feed, oxygen-blown, up-flow gasifier, with and without CO_2 capture, PRB and ND lignite coals
	Single-stage, dry-feed, oxygen-blown, up-flow gasifier without CO_2 capture, Illinois #6 coal
9	Transport gasifier, air- and oxygen-blown, with and without CO_2 capture, PRB and TX lignite coals
	Transport gasifier, oxygen-blown with CO_2 capture, TX lignite coal, with hybrid poplar
NGCC	
10	Natural gas, air-fired, with and without CO_2 capture
	Natural gas, air-fired with CO_2 capture and gas recycle

[1] Ultra-supercritical PC plants have a 10-percent process contingency applied to line item 4.1 (PC Boiler and Accessories) and a 15-percent process contingency applied to line item 8.1 (Steam Turbine Generator and Accessories).

Exhibit 1-2 Reference cost estimates

Category	Technologies
PC/CFBC	
1	*Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity*
	Greenhouse Gas Reductions in the Power Industry Using Domestic Coal and Biomass NETL – Volume 2: PC Plants
	Advanced Oxycombustion Technology for Bituminous Coal Power Plants: An R&D Guide
2	*Cost and Performance Baseline for Fossil Energy Plants – Volume 3: Low Rank Coal and Natural Gas to Electricity*
	Advanced Oxycombustion Technology for Bituminous Coal Power Plants: An R&D Guide
3	*Cost and Performance Baseline for Fossil Energy Plants – Volume 3: Low Rank Coal and Natural Gas to Electricity*
4	*Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity*
5	*Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity*
IGCC	
6	*Cost and Performance Baseline for Fossil Energy Plants – Volume 3: Low Rank Coal and Natural Gas to Electricity*
7	*Cost and Performance Baseline for Fossil Energy Plants – Volume 3: Low Rank Coal and Natural Gas to Electricity*
8	*Cost and Performance Baseline for Fossil Energy Plants – Volume 3: Low Rank Coal and Natural Gas to Electricity*
	Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity
9	*Cost and Performance Baseline for Fossil Energy Plants – Volume 3: Low Rank Coal and Natural Gas to Electricity*
NGCC	
10	*Cost and Performance Baseline for Fossil Energy Plants – Volume 3: Low Rank Coal and Natural Gas to Electricity*
	Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity

1.1 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 #6, both the scaling exponents and the reference cost should be for a plant that fires Illinois #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 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% versus 3 x 50%).

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.

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.

1.2 Methodology

When developing a cost estimate for a plant that requires scaled costing, determine the category type from the category matrix in Exhibit 1-1 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 1-2. Reference cost estimates may also be found on the *NETL Energy Analysis web site*[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 1.1.

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 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 2-2 through Exhibit 2-43 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 2-2 through Exhibit 2-43. If the value is outside the recommended range, significant deviation from realistic results could occur.

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. Specific guidelines are available in subsections, as follows:

2.1 “PC and CFBC”

2.2 “IGCC”

2.3 “NGCC”

The following subsection provides an example for developing cost estimates.

[1] http://www.netl.doe.gov/energy-analyses/index.html

1.3 Scaled Cost Estimate Development Examples

The plant of interest:

The plant of interest 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 category matrix (Exhibit 1-1) 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 3: Low Rank Coal and Natural Gas to Electricity*" (Exhibit 1-2) and Case 4 from the Category 8 report, "*Cost and Performance Baseline for Fossil Energy Power Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity*" (Exhibit 1-2).

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 section that will be utilized in the example will be Account 5 “Gas Cleanup and Piping”

Obtain Scaling Parameters

Exhibit 2-21 contains the scaling parameters, exponents, coefficients, and ranges for Account 5 of the selected category 7 plant type.

Exhibit 1-3 provides the account number, item description, scaling parameter, exponent and coefficient, range of applicability, reference parameter value, reference cost, and scaling parameter value.

Exhibit 1-3 Example Account 5: Parameter listing

Account Number	Item Description	Parameter[1]	Exponent [Coefficient][1]	Range[1]	Reference Parameter[2]	Reference Cost (Equipment/ TPC)[2]	Scaling Parameter[3]
5A.1	Selexol (Double)	Gas flow to AGR, acfm	0.79	5,000 – 30,000	11,389	$73,047	12,068
5A.2	Elemental Sulfur Plant	Sulfur Production, lb/hr	0.67	200 – 44,000	4,901	$5,613	5,339
5A.3	Mercury Removal	Hg bed carbon fill, ft^3	See Note[4]	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	6,692
5A.5	Blowback Gas Systems	Candle filter flow rate, acfm	0.30	2,000 – 96,000	24,282	$2,030	26,838
5A.6	Fuel Gas Piping	Fuel gas flow, lb/hr	0.72	185,000 – 2,490,000	202,347	$0	221,487
5A.9	HGCU Foundations	Sulfur Production, lb/hr	0.79	200 – 44,000	4,901	$0	5,339

[1] Information from exhibits in this document
[2] Information from the 'reference' plant report
[3] Scaling parameter from the 'plant of interest'
[4] The exponent 1.57 is used with PRB coal, the exponent 1.64 is used with Illinois #6 coal without CO_2 capture, and the exponent 1.59 is used with Illinois #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 RC, likewise, when calculating the scaled plant's material cost, one should use the reference plant's material cost as the RC, etc. The sum of these costs is the bare erected cost (BEC).

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

Equation 2

$$SCon = \frac{RCon}{RBEC}$$

Where:

- SCon – Scaled plant's contingency, %
- RCon – Reference plant's contingency, $
- RP – 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.6 and 5A.9 will not be demonstrated, as their 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 within this document.

Based on the general guidelines provided in Section 2 along with the specific guidelines provided in section 2.2 for IGCC plants, the following equations will be utilized:

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

Equation 3

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

For IGCC categories, use Equation 9 for items that utilize a coefficient in addition to an exponent.

Equation 9

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

Where:

- SC – Scaled cost
- RC– Reference cost
- SP – Scaling parameter
- RP – Reference parameter
- Exp – Exponent
- RTPC – Reference total plant cost for subaccount
- STPC – Scaled total plant cost for subaccount
- C – Coefficient

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

Example 1

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

Based on the Note for Account 5A.3, it contains a coefficient. Therefore, this account will use Equation 9 with the parameter "Hg bed carbon fill" in ft^3. The equation is as follows:

Example 2

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

All other subaccounts will use Equation 3 as was demonstrated in Example 1. Exhibit 1-4 provides the results of the calculations and compares them to the reference value.

Exhibit 1-4 Example Account 5: 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.5	Blowback Gas Systems	Candle filter flow rate, acfm	24,282	$2,030	26,838	$2,092

2 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 3 is used to scale costs.

Equation 3

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

Where:

- SC – Scaled cost
- SP – Scaling parameter

2.1 PC and CFBC

For PC and CFBC categories, use Equation 4 for items that utilize a coefficient in addition to an exponent. In the "Scaling parameters and exponents" tables below, the values presented within brackets [] are coefficients.

Equation 4

$$SC = \frac{RC}{RTPC} * (C * SP)^{Exp}$$

Where:

- RTPC – Reference Total Plant Cost of subaccount
- C – Coefficient

Exhibit 2-1 provides the category matrix for the PC and CFBC categories.

Exhibit 2-1 Category matrix: PC and CFBC

Category	Technologies
1	Supercritical PC, air-fired, with and without CO_2 capture, Illinois #6 coal with hybrid poplar
	Supercritical PC, oxy-fired, with CO_2 capture, Illinois #6 coal with hybrid poplar
	Supercritical and ultra-supercritical[1] PC, oxy-fired, with CO_2 capture, Illinois #6 coal
2	CFBC, air-fired, with and without CO_2 capture, PRB and ND Lignite coals
	CFBC, oxy-fired, with CO_2 capture, PRB and ND Lignite coals
3	Supercritical PC, air-fired, with and without CO_2 capture, ND lignite and PRB coals
	Ultra-supercritical PC[1], air-fired, with and without CO_2 capture, ND lignite and PRB coals
	Supercritical PC, oxy-fired, with CO_2 capture, ND lignite and PRB coals
	Ultra-supercritical PC[1], oxy-fired, with CO_2 capture, ND lignite and PRB coals
4	Supercritical and ultra-supercritical[1] PC, air-fired, with and without CO_2 capture, Illinois #6 coal
5	Subcritical PC, air-fired, with and without CO_2 capture, Illinois #6 coal

Exhibit 2-2 through Exhibit 2-15 contains the scaling parameters and exponents that are suitable for PC and CFBC plants at the given ranges.

[1] Ultra-supercritical PC plants have a 10 percent process contingency applied to line item 4.1 (PC Boiler and Accessories) and a 15 percent process contingency applied to line item 8.1 (Steam Turbine Generator and Accessories).

Exhibit 2-2 Scaling parameters and exponents for categories 1-5: "Fuel and Sorbent Handling"

Account Number	Item Description	Parameter	Exponent					Range
Category		1-5	1	2	3	4	5	1-5
1	FUEL & SORBENT HANDLING							
1.1	Coal Receive & Unload	Coal Feed Rate, lb/hr	0.62					275,000 – 1,110,000
1.2	Coal Stackout & Reclaim	Coal Feed Rate, lb/hr	0.62					275,000 – 1,110,000
1.3	Coal Conveyors & Yard Crushing	Coal Feed Rate, lb/hr	0.62					275,000 – 1,110,000
1.4	Other Coal Handling	Coal Feed Rate, lb/hr	0.62					275,000 – 1,110,000
1.5	Biomass Receiving & Processing	Biomass Feed Rate, lb/hr	See Note[1]					412,000 – 616,000
1.6	Sorbent Receive & Unload	Limestone Feed Rate, lb/hr	0.64					9,000 – 63,000
1.7	Sorbent Stackout & Reclaim	Limestone Feed Rate, lb/hr	0.64					9,000 – 63,000
1.8	Sorbent Conveyors	Limestone Feed Rate, lb/hr	0.64					9,000 – 63,000
1.9	Other Sorbent Handling	Limestone Feed Rate, lb/hr	0.64					9,000 – 63,000
1.10	Coal & Sorbent Handling Foundations	Coal and Limestone Feed Rate, lb/hr	0.62					302,000 – 1,150,000

Equation 5

$$SC = 215,062 * \left(\frac{SP}{2000} * 24\right)^{Exp}$$

Equation 6

$$SC = 132,454 * \left(\frac{SP}{2000} * 24\right)^{Exp}$$

[1] Only applicable to plants co-firing hybrid poplar. Use Equation 5 with exponent 0.37 for equipment and Equation 6 with exponent 0.45 for direct labor. Values provided in $1,000 (2007$).

Exhibit 2-3 Scaling parameters and exponents for categories 1-5: "Fuel and Sorbent Prep and Feed"

Account Number	Item Description	Parameter	Exponent					Range
Category		1-5	1	2	3	4	5	1-5
2	FUEL & SORBENT PREP & FEED							
2.1	Coal Crushing & Drying	Coal Feed Rate, lb/hr	0.66					275,000 – 1,110,000
2.2	Prepared Coal Storage & Feed	Coal Feed Rate, lb/hr	0.66					275,000 – 1,110,000
2.5	Biomass Drying	Biomass Feed Rate, lb/hr	0.66[1]					412,000 – 616,000
2.6	Biomass Pelletization	Biomass Feed Rate, lb/hr	0.66[2]					412,000 – 616,000
2.7	Prepared Biomass Storage & Feed	Biomass Feed Rate, lb/hr	0.66					412,000 – 616,000
2.8	Sorbent Prep Equipment	Limestone Feed Rate, lb/hr	0.65					10,000 – 57,000
2.9	Sorbent Storage & Feed	Limestone Feed Rate, lb/hr	0.65					10,000 – 57,000
2.12	Coal & Sorbent Feed Foundation	Coal and Limestone Feed Rate, lb/hr	0.64					303,000 – 1,150,000

Equation 7

$$SC = \mathrm{C} * \left(\frac{SP}{2000} * 24\right)^{Exp}$$

Equation 8

$$SC = RC * \left(\frac{SP}{10 * 1.1 * 2000}\right)^{Exp}$$

[1] Only applicable to plants co-firing hybrid poplar. Use Equation 7 with a coefficient of 7.0428 for equipment and 1.3724 for direct labor. Values provided in $1,000 (2007$).
[2] Only applicable to plants co-firing hybrid poplar. Use Equation 8 for equipment.

Exhibit 2-4 Scaling parameters and exponents for categories 1-5: "Feedwater and Miscellaneous BOP Systems"

Account Number	Item Description	Parameter	Exponent					Range
Category		1-5	1	2	3	4	5	1-5
3	FEEDWATER & MISC. BOP SYSTEMS							
3.1	Feedwater System	HP BFW Flow Rate, lb/hr	0.68					1,960,000 – 5,600,000
3.2	Water Makeup & Pretreating	Raw Water Makeup, gpm	0.71					2,000 – 11,000
3.3	Other Feedwater Subsystems	HP BFW Flow Rate, lb/hr	0.68					1,960,000 – 5,600,000
3.4	Service Water Systems	Raw Water Makeup, gpm	0.71					2,000 – 11,000
3.5	Other Boiler Plant Systems	HP BFW Flow Rate, lb/hr	0.75					1,960,000 – 5,600,000
3.6	FO Supply Sys & Nat Gas	Total Fuel Feed, lb/hr	0.25					410,000 – 1,110,000
3.7	Waste Treatment Equipment	Water to Treatment, lb/hr	0.71					100 – 1,210,000
3.8	Misc. Power Plant Equipment	Total Fuel Feed, lb/hr	0.25					410,000 – 1,110,000

Exhibit 2-5 Scaling parameters and exponents for categories 1-5: "PC Boiler and Accessories"

Account Number	Item Description	Parameter	Exponent					Range
Category		1-5	1	2	3	4	5	1-5
4	PC BOILER & ACCESSORIES							
4.1	PC Boiler & Accessories	See Note[1]	0.69					See Note[1]
4.2	ASU/Oxidant Compression	O_2 Flow Rate, TPD	0.60					13,200 – 15,100

[1] CFBC plants use the sum of limestone and coal feed rates (lb/hr) with the total ranging from 303,000 – 1,150,000; Oxy-fired PC with no biomass use coal-feed rates (lb/hr) ranging from 275,000 – 1,112,000; PC air-fired and PC with biomass use high pressure (HP) boiler feed water (BFW) flow rates (lb/hr) ranging from 1,958,000 – 5,603,000.

Exhibit 2-6 Scaling parameters and exponents for categories 1-5: "Flue Gas cleanup"

Account Number	Item Description	Parameter	Exponent [Coefficient]					Range
Category		1-5	1	2	3	4	5	1-5
5	FLUE GAS CLEANUP							
5.1	Absorber Vessels & Accessories	FGD Exit Flow, acfm {Limestone Feed Rate, lb/hr}	0.73 [3.08]	N/A	0.59 [23.75][1]	{0.73}	0.73	1,020,000 – 2,560,000 9,000 – 63,400
5.2	Other FGD	FGD Exit Flow, acfm {Limestone Feed Rate, lb/hr}	0.73 [0.28]	N/A	0.49[2]	{0.73}	0.73	1,020,000 – 2,560,000 9,000 – 63,400
5.3	Bag House & Accessories	Baghouse Flow, acfm	0.78 [0.47]	N/A	N/A	0.79	0.79	1,390,000 – 2,560,000
5.4	Other Particulate Removal Materials	Baghouse Flow, acfm	0.77	N/A	0.40 [112.22][3]	0.79	0.79	1,390,000 – 2,560,000
5.5	Gypsum Dewatering System	Gypsum Flow, lb/hr	0.62	N/A	N/A	0.58	0.60	42,900 – 96,600

Exhibit 2-7 Scaling parameters and exponents for categories 1-5: "CO_2 Removal and Compression"

Account Number	Item Description	Parameter	Exponent [Coefficient]					Range
Category		1-5	1	2	3	4	5	1-5
5B	CO_2 REMOVAL & COMPRESSION							
5B.1	CO_2 Condensing Heat Exchanger	Heat Duty, MMBtu/hr	0.80	0.80	0.80			200 – 600
	CO_2 Removal System	CO_2 Flowrate (lb/hr)/ Inlet to Absorber, acfm	0.60[4]	N/A		0.60[4]	0.60[4]	445,000 – 689,000/ N/A[5]
5B.2	CO_2 Compression & Drying	CO_2 Captured, lb/hr	0.61					850,000 – 2,290,000

[1] Ultra-supercritical plants use a coefficient of 25.9090 and an exponent of 0.5810.
[2] Ultra-supercritical plants use an exponent of 0.46.
[3] Ultra-supercritical plants use a coefficient of 92.44 and an exponent of 0.4152.
[4] 40% of cost is applied to gas flow and the remainder applied to CO_2 capture.
[5] Range has not yet been developed as parameter has not been implemented to date.

Exhibit 2-8 Scaling parameters and exponents for categories 1-5: "HRSG, Ducting, and Stack"

Account Number	Item Description	Parameter	Exponent [Coefficient]					Range
Category		1-5	1	2	3	4	5	1-5
7	HRSG, DUCTING & STACK							
7.1	Flue Gas Recycle Heat Exchanger	Heat Duty, MMBtu/hr	0.80					20 – 1,000
7.3	Ductwork	Total Fuel Feed, lb/hr	0.38 [126.25]	0.38 [126.25]	0.38 [126.25]	0.29	0.29	410,000 – 1,110,000
7.4	Stack	Stack Flow, acfm	0.48 [19.52]	0.48 [19.52]	0.48 [19.52]	0.06	0.06	378,000 – 1,840,000
7.9	HRSG, Duct & Stack Foundations	Total Fuel Feed, lb/hr	0.14 [471.71]	0.14 [471.71]	0.14 [471.71]	0.06	0.06	410,000 – 1,110,000

Exhibit 2-9 Scaling parameters and exponents for categories 1-5: "Steam Turbine Generator"

Account Number	Item Description	Parameter	Exponent					Range
Category		1-5	1	2	3	4	5	1-5
8	STEAM TURBINE GENERATOR							
8.1	Steam TG & Accessories	Turbine Capacity, MW	0.70					600 – 800
8.2	Turbine Plant Auxiliaries	Turbine Capacity, MW	0.70					600 – 800
8.3a	Condenser & Auxiliaries	Condenser Duty, MMBtu/hr	0.67	0.67	0.67	0.67	0.40	1,000 – 3,000
8.3b	Air Cooled Condenser	Condenser Duty, MMBtu/hr	N/A	N/A	N/A	0.70	N/A	1,000 – 3,000
8.4	Steam Piping	HP BFW Flow Rate, lb/hr	0.70					1,960,000 – 5,600,000
8.9	TG Foundations	Turbine Capacity, MW	0.71					600 – 800

Exhibit 2-10 Scaling parameters and exponents for categories 1-5: "Cooling Water System"

Account Number	Item Description	Parameter	Exponent					Range
Category		1-5	1	2	3	4	5	1-5
9	COOLING WATER SYSTEM							
9.1	Cooling Towers	Cooling Tower Duty, MMBtu/hr	0.74					1000 – 6,000
9.2	Circulating Water Pumps	Circulating Water Flow Rate, gpm	0.86	0.73	0.73	0.86	0.73	115,000 – 550,000
9.3	Circ. Water System Auxiliaries	Circulating Water Flow Rate, gpm	0.63					115,000 – 550,000
9.4	Circ. Water Piping	Circulating Water Flow Rate, gpm	0.63					115,000 – 550,000
9.5	Make-up Water System	Raw Water Makeup, gpm	0.64	0.64	0.64[1]	0.64	0.64	2,000 – 11,200
9.6	Component Cooling Water System	Circulating Water Flow Rate, gpm	0.63					115,000 – 550,000
9.9	Circ. Water System Foundations	Circulating Water Flow Rate, gpm	0.58					115,000 – 550,000

Exhibit 2-11 Scaling parameters and exponents for categories 1-5: "Ash and Spent Sorbent Handling System"

Account Number	Item Description	Parameter	Exponent					Range
Category		1-5	1	2	3	4	5	1-5
10	ASH/SPENT SORBENT HANDLING SYSTEM							
10.6	Ash Storage Silos	Total Ash Flow, lb/hr	0.56					10 – 100
10.7	Ash Transport & Feed Equipment	Total Ash Flow, lb/hr	0.56					10 – 100
10.9	Ash/Spent Sorbent Foundation	Total Ash Flow, lb/hr	0.56					10 – 100

[1] The exponent 0.82 should be used with ultra-supercritical plants.

Exhibit 2-12 Scaling parameters and exponents for categories 1-5: "Accessory Electric Plant"

Account Number	Item Description	Parameter	Exponent [Coefficient]					Range
Category		1-5	1	2	3	4	5	1-5
11	ACCESSORY ELECTRIC PLANT							
11.1	Generator Equipment	Turbine Capacity, MW	0.57					600 – 800
11.2	Station Service Equipment	Auxiliary Load, kW	0.43					28,300 – 272,000
11.3	Switchgear & Motor Control	Auxiliary Load, kW	0.43					28,300 – 272,000
11.4	Conduit & Cable Tray	Auxiliary Load, kW	0.43					28,300 – 272,000
11.5	Wire & Cable	Auxiliary Load, kW	0.43					28,300 – 272,000
11.6	Protective Equipment	Auxiliary Load, kW	0.00					28,300 – 272,000
11.7	Standby Equipment	Turbine Capacity, MW	0.46					588 – 835
11.8	Main Power Transformers	STG Rating, MVA	0.46 [418.03]	0.46 [418.03]	0.46 [418.03]	0.48	2.11	10 – 1000
11.9	Electrical Foundations	Turbine Capacity, MW	0.69					600 – 800

Exhibit 2-13 Scaling parameters and exponents for categories 1-5: "Instrumentation and Control"

Account Number	Item Description	Parameter	Exponent [Coefficient]					Range
Category		1-5	1	2	3	4	5	1-5
12	INSTRUMENTATION & CONTROL							
12.6	Control Boards, Panels & Racks	Auxiliary Load, kW	0.13					28,300 – 272,000
12.7	Computer Accessories	Auxiliary Load, kW	0.13					28,300 – 272,000
12.8	Instrument Wiring & Tubing	Auxiliary Load, kW	0.13					28,300 – 272,000
12.9	Other I & C Equipment	Auxiliary Load, kW	0.13					28,300 – 272,000

Exhibit 2-14 Scaling parameters and exponents for categories 1-5: "Improvements to Site"

Account Number	Item Description	Parameter	Exponent					Range
Category		1-5	1	2	3	4	5	1-5
13	IMPROVEMENTS TO SITE							
13.1	Site Preparation	BEC (Minus Acts. 13 and 14)	0.20					735,000 – 1,630,000
13.2	Site Improvements	BEC (Minus Acts. 13 and 14)	0.20					735,000 – 1,630,000
13.3	Site Facilities	BEC (Minus Acts. 13 and 14)	0.20					735,000 – 1,630,000

Exhibit 2-15 Scaling parameters and exponents for categories 1-5: "Buildings and Structures"

Account Number	Item Description	Parameter	Exponent					Range
Category		1-5	1	2	3	4	5	1-5
14	BUILDINGS & STRUCTURES							
14.1	Boiler Building	BEC (Minus Acts. 13 and 14)	0.09					735,000 – 1,630,000
14.2	Turbine Building	BEC (Minus Acts. 13 and 14)	0.12					735,000 – 1,630,000
14.3	Administration Building	BEC (Minus Acts. 13 and 14)	0.10					735,000 – 1,630,000
14.4	Circulation Water Pumphouse	Circulating Water Flow Rate, gpm	0.60					115,000 – 550,000
14.5	Water Treatment Buildings	Raw Water Makeup, gpm	0.65					2,000 – 11,200
14.6	Machine Shop	BEC (Minus Acts. 13 and 14)	0.10					735,000 – 1,630,000
14.7	Warehouse	BEC (Minus Acts. 13 and 14)	0.10					735,000 – 1,630,000
14.8	Other Buildings & Structures	BEC (Minus Acts. 13 and 14)	0.10					735,000 – 1,630,000
14.9	Waste Treating Building & Structures	Raw Water Makeup, gpm	0.07					2,000 – 11,200

2.2 IGCC

Exhibit 2-16 provides the category matrix for IGCC categories.

Exhibit 2-16 Category matrix: IGCC

Category	Technologies
6	Single-stage, dry-feed, oxygen-blown, down-flow gasifier with and without CO_2 capture, PRB and ND lignite coals
7	Two-stage, slurry-feed, oxygen-blown gasifier with and without CO_2 capture, PRB coal
	Single-stage, slurry-feed, oxygen-blown gasifier with and without CO_2 capture, Illinois #6 coal
8	Single-stage, dry-feed, oxygen-blown, up-flow gasifier,with CO_2 capture, PRB coal with and without switchgrass
	Single-stage, dry-feed, oxygen-blown, up-flow gasifier with CO_2 capture, Illinois #6 coal with switchgrass
	Single-stage, dry-feed, oxygen-blown, up-flow gasifier, with and without CO_2 capture, PRB and ND lignite coals
	Single-stage, dry-feed, oxygen-blown, up-flow gasifier without CO_2 capture, Illinois #6 coal
9	Transport gasifier, air- and oxygen-blown, with and without CO_2 capture, PRB and TX lignite coals
	Transport gasifier, oxygen-blown with CO_2 capture, TX lignite coal, with hybrid poplar

For IGCC categories, use Equation 9 for items that utilize a coefficient in addition to an exponent. In the "scaling parameters and exponents" tables below, the values presented within brackets [] are coefficients.

Equation 9

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

Exhibit 2-17 through Exhibit 2-31 contain the scaling parameters and exponents that are suitable for IGCC plants at the given ranges.

Exhibit 2-17 Scaling parameters and exponents for categories 6-9: "Fuel and Sorbent Handling"

Account Number	Item Description	Parameter	Exponent				Range
Category		6-9	6	7	8	9	6-9
1	FUEL & SORBENT HANDLING						
1.1	Coal Receive & Unload	Coal feed rate, lb/hr	0.62				18,400 – 1,750,000
1.2	Coal Stackout & Reclaim	Coal feed rate, lb/hr	0.62				18,400 – 1,750,000
1.3	Coal Conveyors & Yd Crush	Coal feed rate, lb/hr	0.62				18,400 – 1,750,000
1.4	Other Coal Handling	Coal feed rate, lb/hr	0.62				18,400 – 1,750,000
1.5	Biomass Receive & Unload	Biomass Feed, lb/hr	0.62	0.62	0.62	See Note[1]	6,000 – 934,000
1.6	Biomass Handling	Biomass Feed, lb/hr	0.62				6,000 – 934,000
1.7	Biomass Conveyors	Biomass Feed, lb/hr	0.62				6,000 – 934,000
1.8	Biomass Handling Foundations	Biomass Feed, lb/hr	0.62				6,000 – 934,000
1.9	Coal & Sorbent Handling Foundations	Coal feed rate, lb/hr	0.62				18,400 – 1,750,000

[1] Use Equation 5 with exponent 0.37 for equipment and Equation 6 with exponent 0.45for direct labor. Values provided in $1,000 (2007$).

Exhibit 2-18 Scaling parameters and exponents for categories 6-9: "Fuel and Sorbent Prep and Feed"

Account Number	Item Description	Parameter	Exponent [Coefficient]				Range
Category		6-9	6	7	8	9	6-9
2	FUEL & SORBENT PREP & FEED						
2.1	Coal Crushing & Drying	Coal feed rate, lb/hr	0.66				18,400 – 1,750,000
2.2	Prepared Coal Storage & Feed	Coal feed rate, lb/hr	0.66				18,400 – 1,750,000
2.3	Dry Coal Injection System/ Slurry Prep and Feed	Coal feed rate, lb/hr	0.66				18,400 – 1,750,000
2.4	Misc. Coal Prep & Feed	Coal feed rate, lb/hr	0.66	0.66	0.66	0.90	18,400 – 1,750,000
2.5	Biomass Shredding & Drying	Biomass Feed, lb/hr	0.66[1]				6,000 – 934,000
2.6	Biomass Pelletization/ Dry Biomass Injection System	Biomass Feed, lb/hr	0.66				6,000 – 934,000
2.7	Prepared Biomass Storage & Feed	Biomass Feed, lb/hr	0.66				6,000 – 934,000
2.9	Coal & Sorbent Feed Foundation	Total Feed Flow Rate, lb/hr	0.66				467,100 – 1,750,000

Equation 7

$$SC = \mathrm{C} * \left(\frac{SP}{2000} * 24\right)^{Exp}$$

[1] For oxygen-blown transportation gasification with CO_2 capture firing TX lignite coal with hybrid poplar co-fire, use Equation 7 with a coefficient of 7.0428 to calculate equipment costs and a coefficient of 1.3724 to calculate direct labor costs. Values are provided in $1,000 (2007$).

Exhibit 2-19 Scaling parameters and exponents for categories 6-9: "Feedwater and Miscellaneous BOP Systems"

Account Number	Item Description	Parameter	Exponent [Coefficient]				Range
Category		6-9	6	7	8	9	6-9
3	FEEDWATER & MISC. BOP SYSTEMS						
3.1	Feedwater System	BFW (HP only), lb/hr	0.71				1,000 – 4,000
3.2	Water Makeup & Pretreating	Raw water makeup, gpm	0.71				300 – 9,000
3.3	Other Feedwater Subsystems	BFW (HP only), lb/hr	0.71				1,000 – 4,000
3.4	Service Water Systems	Raw water makeup, gpm	0.71				300 – 9,000
3.5	Other Boiler Plant Systems	Raw water makeup, gpm	0.73	0.73	0.73	0.25	300 – 9,000
3.6	FO Supply Sys & Nat Gas	Total Feed Flow Rate, lb/hr	0.00	0.24	0.24	0.00	467,000 – 1,750,000
3.7	Waste Treatment Equipment	Raw water makeup, gpm	0.71				300 – 9,000
3.8	Misc. Power Plant Equipment	Total Feed Flow Rate, lb/hr	0.66	0.24	0.24	0.06	467,000 – 1,750,000

Exhibit 2-20 Scaling parameters and exponents for categories 6-9: "Gasifier and Accessories"

Account Number	Item Description	Parameter	Exponent [Coefficient]				Range
Category		6-9	6	7	8	9	6-9
4	GASIFIER & ACCESSORIES						
4.1	Gasifier, Syngas Cooler & Auxiliaries	SGC Duty/Total Feed Flow Rate, lb/hr	0.00	0.77/1.19 [0.29/0.71][1]	0.53 [214.0][2]	0.31/0.64 [0.51/0.49][1]	200 – 1,000 467,000 – 1,750,000
4.3	ASU/Oxidant Compression	O_2 Production, lb/hr/MAC Power, kW	2.39/0.89 [0.09/0.91][1]	0.70/0.70 [0.50/0.50][1]	0.70/0.54 [0.80/0.20][3]	0.36/0.36[4] [0.50/0.50][1]	285,000 – 1,750,000 5,000 – 316,000
4.4	LT Heat Recovery & FG Saturation/ Scrubber & Low Temperature Cooling	Total Feed Flow Rate, lb/hr	See Note[5]	See Note[6]	See Note[6]	0.40	467,000 – 1,750,000
4.6	Flare Stack System/ Soot Recovery & SARU/ Other Gasification Equipment	Total Feed Flow Rate, lb/hr	See Note[7]	0.50	0.50	0.40	467,000 – 1,750,000
4.9	Gasification Foundations	Total Feed Flow Rate, lb/hr	0.50	0.50	0.50	0.40	467,000 – 1,750,000

Equation 10

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

Equation 11

$$SC = \frac{RC}{RTPC} * (40{,}689 * DCF^{0.136} + 289{,}128 * DCF)$$

Equation 12

$$\boldsymbol{STPC} = \mathbf{10}^{\left[\frac{(52.825736*\log_{10} SP^3)-(924.074743*\log_{10} SP^2)+}{(5388.117529*\log_{10} SP)-10468.642234}\right]}$$

Equation 13

$$SC = C_1 * RC_1 * SP_1^{Exp} + C_2 * RC_2 * SP_2^{Exp}$$

Where:

- STPC – Scaled total plant cost
- DCF – Dry coal feed, lb/hr

[1] Use Equation 10.
[2] Non-biomass plants with PRB or ND Lignite coal use Equation 11. Non-biomass plants with Illinois #6 coal use exponent 0.66 with Equation 3.
[3] Biomass plants use Equation 13, values provided in $1,000 (2007$). Non-biomass plants use Equation 10 with Exponents of 0.70/0.70 and Coefficients of 0.50/0.50.
[4] TRIG air-fired plants scale on combustion turbine extraction air flow rate, lb/hr, rather than O_2 production rate.
[5] For capture plants, the TPC is 22.0 percent of the TPC of the "Gasifier, Syngas Cooler &Auxiliaries." For non-capture plants, the TPC is 23.0 percent.
[6] For capture plants, the TPC is 20.6 percent of the TPC of the "Gasifier, Syngas Cooler &Auxiliaries." For non-capture plants with PRB or ND Lignite coals, the TPC is 10.7 percent. For non-capture plants with Illinois #6 coal, use exponent of 0.23 with Equation 3.
[7] Use Equation 12.

Exhibit 2-21 Scaling parameters and exponents for categories 6-9: "Gas Cleanup and Piping"

Account Number	Item Description	Parameter	Exponent [Coefficient]				Range
Category		6-9	6	7	8	9	6-9
5	GAS CLEANUP & PIPING						
5A.1	Sulfinol/Selexol (Single and Double)/MDEA-LT	Gas flow to AGR, acfm	1.44	0.79	0.79	0.95	6,000 – 30,500
5A.2	Elemental Sulfur Plant	Sulfur Production, lb/hr	0.67	0.67	0.58 [131.42][1]	0.67	300 – 43,900
5A.3	Mercury Removal	Hg bed carbon fill, ft^3	0.69 [11.05]	See Note[2]	0.034 [1.461][3]	0.70	2,000 – 35,100
5A.4	Shift Reactors/ COS Hydrolysis	WGS Catalyst volume, ft^3/ COS Catalyst volume, ft^3	0.12	0.80	0.59/0.78	0.75	2,000 – 10,600 9,000 – 25,500
5A.5	Blowback Gas Systems	Candle filter flow rate, acfm	N/A	0.30	0.75[4]	0.41	2,000 – 96,000
5A.6	Fuel Gas Piping	Fuel gas flow, lb/hr	0.7224 [2.282]	0.72	0.78 [1.87][5]	0.58	185,000 – 2,490,000
5A.9	HGCU Foundations	Sulfur Production, lb/hr	0.79	0.79	0.52[6]	0.79	300 – 43,900

[1] Non-biomass plants use the exponent 0.67 and coefficient 61.981.
[2] Use exponent 1.57 with PRB coal, use exponent 1.64 with Illinois #6 coal without CO_2 capture, and use exponent 1.59 with Illinois #6 coal with CO_2 capture. The coefficient 0.0141 is used with all plants.
[3] Non-biomass plants with Illinois #6 coal, use Equation 3 with an exponent of 0.60. All other non-biomass plants use the coefficient of 0.0141 and exponent of 1.5742.
[4] Non-biomass plants use the exponent of 0.30.
[5] Non-biomass plants use the coefficient 2.282 and exponent 0.7224.
[6] Non-biomass plants use the exponent of 0.79.

Exhibit 2-22 Scaling parameters and exponents for categories 6-9: "CO_2 Compression"

Account Number	Item Description	Parameter	Exponent				Range
Category		6-9	6	7	8	9	6-9
5B	CO_2 COMPRESSION						
5B.2	CO_2 Compression & Drying	Compressor Power, kW	0.63	0.88	{0.88}[1]	0.67	28,300 – 43,500 1,000,000 – 2,200,000

Exhibit 2-23 Scaling parameters and exponents for categories 6-9: "Combustion Turbine and Accessories"

Account Number	Item Description	Parameter	Exponent				Range
Category		6-9	6	7	8	9	6-9
6	COMBUSTION TURBINE/ACCESSORIES						
6.1	Combustion Turbine Generator	Fuel gas flow, lb/hr	0.00				185,000 – 2,490,000
6.9	Combustion Turbine Foundations	Fuel gas flow, lb/hr	0.00				185,000 – 2,490,000

Exhibit 2-24 Scaling parameters and exponents for categories 6-9: "HRSG, Ducting, and Stack"

Account Number	Item Description	Parameter	Exponent				Range
Category		6-9	6	7	8	9	6-9
7	HRSG, DUCTING & STACK						
7.1	Heat Recovery Steam Generator	HRSG duty, MMBtu/hr	0.70				600 – 5,000
7.3	Ductwork	volumetric flow to stack, acfm	0.70	0.70	0.70	0.57	1,010,000 – 2,810,000
7.4	Stack	volumetric flow to stack, acfm	0.70				1,010,000 – 2,810,000
7.9	HRSG,Duct & Stack Foundations	volumetric flow to stack, acfm	0.70	0.70	0.70	0.67	1,010,000 – 2,810,000

[1] Biomass plants use the exponent 0.79 with the scaling parameter "CO_2 Captured, lb/hr."

Exhibit 2-25 Scaling parameters and exponents for categories 6-9: "Steam Turbine Generator"

Account Number	Item Description	Parameter	Exponent [Coefficient]				Range
Category		6-9	6	7	8	9	6-9
8	STEAM TURBINE GENERATOR						
8.1	Steam TG & Accessories	Turbine capacity, kW	0.70				195,000 – 371,000
8.2	Turbine Plant Auxiliaries	Turbine capacity, kW	0.72				195,000 – 371,000
8.3a	Condenser & Auxiliaries	Condenser duty, MMBtu/hr	0.71	0.71	0.70 [52.90][1]	0.71	500 – 2,000
8.3b	Air Cooled Condenser	BFW (HP only), lb/hr {Condenser Duty, MMBtu/hr}	0.36	0.73	{0.70}	1.14	1,000 – 4,000 500 – 2,000
8.4	Steam Piping	BFW (HP only), lb/hr	0.72	0.72	0.63 [122.80][2]	0.72	1,000 – 4,000
8.9	TG Foundations	Turbine capacity, kW	0.72				195,000 – 371,000

[1] Non-biomass plants use a coefficient of 45.921 and exponent of 0.7.
[2] Non-biomass plants with PRB or ND Lignite coal use the exponent 0.7018 and coefficient 71.1. Non-biomass plants with Illinois #6 coal use the exponent 0.70 with Equation 3.

Exhibit 2-26 Scaling parameters and exponents for categories 6-9: "Cooling Water System"

Account Number	Item Description	Parameter	Exponent [Coefficient]				Range
Category		6-9	6	7	8	9	6-9
9	COOLING WATER SYSTEM						
9.1	Cooling Towers	Cooling tower duty, MMBtu/hr	0.90	0.72	0.72	0.72	1,000 – 4,000
9.2	Circulating Water Pumps	Circ water flow rate, gpm	0.72	0.72	0.69 [0.54][1]	0.72	92,600 – 330,000
9.3	Circ.Water System Auxiliaries	Circ water flow rate, gpm	0.64				92,600 – 330,000
9.4	Circ.Water Piping	Circ water flow rate, gpm	0.606 [6.185][2]				92,600 – 330,000
9.5	Make-up Water System	Raw water makeup, gpm	0.60				300 – 9,000
9.6	Component Cooling Water System	Circ water flow rate, gpm	0.64				92,600 – 330,000
9.9	Circ.Water System Foundations	Circ water flow rate, gpm	0.59				92,600 – 330,000

Exhibit 2-27 Scaling parameters and exponents for categories 6-9: "Ash and Spent Sorbent Handling System"

Account Number	Item Description	Parameter	Exponent [Coefficient]				Range
Category		6-9	6	7	8	9	6-9
10	ASH/SPENT SORBENT HANDLING SYSTEM						
10.1	Slag Dewatering & Cooling	Slag production, lb/hr	0.64				7,000 – 351,000
10.6	Ash Storage Silos	Slag production, lb/hr	0.55				7,000 – 351,000
10.7	Ash Transport & Feed Equipment	Slag production, lb/hr	0.55				7,000 – 351,000
10.8	Misc. Ash Handling Equipment	Slag production, lb/hr	0.55				7,000 – 351,000
10.9	Ash/Spent Sorbent Foundation	Slag production, lb/hr	0.55				7,000 – 351,000

[1] Non-biomass plants use the coefficient 0.6273 and exponent 0.6714.
[2] Non-biomass plants use the exponent 0.6085 and coefficient 6.0862.

Exhibit 2-28 Scaling parameters and exponents for categories 6-9: "Accessory Electric Plant"

Account Number	Item Description	Parameter	Exponent				Range
Category		6-9	6	7	8	9	6-9
11	ACCESSORY ELECTRIC PLANT						
11.1	Generator Equipment	Turbine capacity, kW	0.54				195,000 – 371,000
11.2	Station Service Equipment	Auxiliary load, kW	0.45				107,000 – 423,000
11.3	Switchgear & Motor Control	Auxiliary load, kW	0.45				107,000 – 423,000
11.4	Conduit & Cable Tray	Auxiliary load, kW	0.45				107,000 – 423,000
11.5	Wire & Cable	Auxiliary load, kW	0.45				107,000 – 423,000
11.6	Protective Equipment	Auxiliary load, kW	0.00	0.00	0.00	0.65	107,000 – 423,000
11.7	Standby Equipment	Total Gross Output, kW	0.48	0.48	0.48	0.00	621,000 – 835,000
11.8	Main Power Transformers	Total Gross Output, kW	0.71	0.71	0.71	0.00	621,000 – 835,000
11.9	Electrical Foundations	Total Gross Output, kW	0.70	0.70	0.70	0.00	621,000 – 835,000

Exhibit 2-29 Scaling parameters and exponents for categories 6-9: "Instrumentation and Control"

Account Number	Item Description	Parameter	Exponent				Range
Category		6-9	6	7	8	9	6-9
12	INSTRUMENTATION & CONTROL						
12.4	Other Major Component Control	Auxiliary load, kW	0.24	0.13	0.13	0.24	107,000 – 423,000
12.6	Control Boards, Panels & Racks	Auxiliary load, kW	0.24	0.13	0.13	0.24	107,000 – 423,000
12.7	Computer & Accessories	Auxiliary load, kW	0.24	0.13	0.13	0.24	107,000 – 423,000
12.8	Instrument Wiring & Tubing	Auxiliary load, kW	0.24	0.13	0.13	0.24	107,000 – 423,000
12.9	Other I & C Equipment	Auxiliary load, kW	0.24	0.13	0.13	0.24	107,000 – 423,000

Exhibit 2-30 Scaling parameters and exponents for categories 6-9: "Improvements to Site"

Account Number	Item Description	Parameter	Exponent				Range
Category		6-9	6	7	8	9	6-9
13	IMPROVEMENTS TO SITE						
13.1	Site Preparation	BEC Accts 1-12	0.34	0.08	0.08	0.34	1,040,000 – 1,680,000
13.2	Site Improvements	BEC Accts 1-12	0.33	0.08	0.08	0.33	1,040,000 – 1,680,000
13.3	Site Facilities	BEC Accts 1-12	0.34	0.08	0.08	0.34	1,040,000 – 1,680,000

Exhibit 2-31 Scaling parameters and exponents for categories 6-9: "Buildings and Structures"

Account Number	Item Description	Parameter	Exponent				Range
Category		6-9	6	7	8	9	6-9
14	BUILDINGS & STRUCTURES						
14.1	Combustion Turbine Area	Gas Turbine Power, kWe	0.00				51,200 – 471,000
14.2	Steam Turbine Building	BEC Accts 1-12	0.17	0.17	0.17	0.45	1,040,000 – 1,680,000
14.3	Administration Building	BEC Accts 1-12	0.00	0.10	0.10	0.00	1,040,000 – 1,680,000
14.4	Circulation Water Pumphouse	Circ water flow rate, gpm	0.01	0.46	0.46	0.46	92,600 – 330,000
14.5	Water Treatment Buildings	Raw water makeup, gpm	0.71				300 – 9,000
14.6	Machine Shop	BEC Accts 1-12	0.32	0.10	0.02	0.00	1,040,000 – 1,680,000
14.7	Warehouse	BEC Accts 1-12	0.32	0.10	0.02	0.00	1,040,000 – 1,680,000
14.8	Other Buildings & Structures	BEC Accts 1-12	0.35	0.10	0.02	0.21	1,040,000 – 1,680,000
14.9	Waste Treating Building & Str.	Raw water makeup, gpm	0.08	0.08	0.08	0.08	300 – 9,000

2.3 NGCC

Exhibit 2-32 provides the category matrix for NGCC categories.

Exhibit 2-32 Category matrix: NGCC

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

Exhibit 2-33 through Exhibit 2-43 contain the scaling parameters and exponents that are suitable for NGCC plants at the given ranges.

Exhibit 2-33 Scaling parameters and exponents for categories 6-9: "Feedwater and Miscellaneous BOP Systems"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
3	FEEDWATER & MISC. BOP SYSTEMS			
3.1	Feedwater System	Feedwater flow (HP only), lb/hr	0.72	886,000 – 1,350,000
3.2	Water Makeup & Pretreating	Raw Water Withdrawal (gpm)	0.71	3,000 – 5,000
3.3	Other Feedwater Subsystems	Feedwater flow (HP only), lb/hr	0.72	886,000 – 1,350,000
3.4	Service Water Systems	Raw Water Withdrawal (gpm)	0.71	3,000 – 5,000
3.5	Other Boiler Plant Systems	Raw Water Withdrawal (gpm)	0.71	3,000 – 5,000
3.6	Natural Gas, incl. pipeline	Fuel gas flow, acfm avg	0.07[1]	2,000 – 4,000
3.7	Waste Treatment Equipment	Raw Water Withdrawal (gpm)	0.71	3,000 – 5,000
3.8	Misc. Equip. (cranes, AirComp., Comm.)	Fuel gas flow, acfm avg	0.76	2,000 – 4,000

Exhibit 2-34 Scaling parameters and exponents for categories 6-9: "Gas Cleanup and Piping"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
5A	GAS CLEANUP & PIPING			
5A.6	Exhaust Gas Recycle System	EGR Flowrate (lb/hr)	1.47	3,150,000 – 3,280,000

[1] 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.

Exhibit 2-35 Scaling parameters and exponents for categories 6-9: "CO_2 Removal and Compression"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
5B	CO_2 REMOVAL & COMPRESSION			
5B.1	CO_2 Removal System	CO_2 Flowrate (lb/hr)/ Inlet to Absorber, acfm	0.61[1]	445,000 – 689,000/ N/A[2]
5B.2	CO_2 Compression & Drying	CO_2 Flowrate (lb/hr)	0.77	445,000 – 689,000

Exhibit 2-36 Scaling parameters and exponents for categories 6-9: "Combustion Turbine and Accessories"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
6	COMBUSTION TURBINE/ACCESSORIES			
6.1	Combustion Turbine Generator	Fuel Gas Flow, acfm	0.00	N/A
6.9	Combustion Turbine Foundations	Gas Turbine Power (kWe)	0.00	421,000 – 811,000

Exhibit 2-37 Scaling parameters and exponents for categories 6-9: "HRSG, Ducting, and Stack"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
7	HRSG, DUCTING & STACK			
7.1	Heat Recovery Steam Generator	HRSG Duty (MMBtu/hr)	0.70	2,000 – 3,000
7.2	HRSG Accessories	HRSG Duty (MMBtu/hr)	1.40	2,000 – 3,000
7.9	HRSG,Duct & Stack Foundations	Stack flow rate, acfm	0.70[3]	2,390,000 – 2,860,000

[1] 40% of cost is applied to gas flow and the remainder is applied to CO_2 capture.
[2] Range has not yet been developed as parameter has not been implemented to date.
[3] Natural gas, air-fired with CO_2 capture and gas recycle uses an exponent of 0.47.

Exhibit 2-38 Scaling parameters and exponents for categories 6-9: "Steam Turbine Generator"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
8	STEAM TURBINE GENERATOR			
8.1	Steam TG & Accessories	Steam Turbine Power (kWe)	0.80	230,000 – 321,000
8.2	Turbine Plant Auxiliaries	Steam Turbine Power (kWe)	0.73	230,000 – 321,000
8.3	Condenser & Auxiliaries	Thermal Input (LHV) (kWth)	See Note[1]	1,100,000 – 1,710,000
8.4	Steam Piping	HRSG Duty (MMBtu/hr)	0.83	2,000 – 3,000
8.9	TG Foundations	Steam Turbine Power (kWe)	0.73	230,000 – 321,000

Exhibit 2-39 Scaling parameters and exponents for categories 6-9: "Cooling Water System"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
9	COOLING WATER SYSTEM			
9.1	Cooling Towers	Cooling Tower Duty (MMBtu/hr)	0.71	1,000 – 3,000
9.2	Circulating Water Pumps	Circulating water flow rate, gpm	0.72	125,000 – 294,000
9.3	Circ.Water System Auxiliaries	Circulating water flow rate, gpm	0.60	125,000 – 294,000
9.4	Circ.Water Piping	Circulating water flow rate, gpm	0.60	125,000 – 294,000
9.5	Make – up Water System	Raw water makeup, gpm	0.60	2,000 – 4,000
9.6	Component Cooling Water Sys	Circulating water flow rate, gpm	0.60	125,000 – 294,000
9.9	Circ.Water System Foundations	Circulating water flow rate, gpm	0.60	125,000 – 294,000

[1] Natural gas, air-fired without CO_2 capture uses the exponent 0.43. Natural gas, air-fired with CO_2 capture uses the exponent 0.12. Natural gas, air-fired with CO_2 capture and gas recycle uses the exponent 0.29.

Exhibit 2-40 Scaling parameters and exponents for categories 6-9: "Accessory Electric Plant"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
11	ACCESSORY ELECTRIC PLANT			
11.1	Generator Equipment	Gross Total (kWe)	0.59	650,000 – 1,130,000
11.2	Station Service Equipment	Net Auxiliary Load (kWe)	0.64	50,700 – 73,500
11.3	Switchgear & Motor Control	Net Auxiliary Load (kWe)	0.64	50,700 – 73,500
11.4	Conduit & Cable Tray	Net Auxiliary Load (kWe)	0.64	50,700 – 73,500
11.5	Wire & Cable	Net Auxiliary Load (kWe)	0.64	50,700 – 73,500
11.6	Protective Equipment	Net Auxiliary Load (kWe)	1.10	50,700 – 73,500
11.7	Standby Equipment	Gross Total (kWe)	0.48	650,000 – 1,130,000
11.8	Main Power Transformers	STG output, MVA PLUS CTG output, MVA	0.70	750 – 820
11.9	Electrical Foundations	Gross Total (kWe)	0.70	650,000 – 1,130,000

Exhibit 2-41 Scaling parameters and exponents for categories 6-9: "Instrumentation and Control"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
12	INSTRUMENTATION & CONTROL			
12.4	Other Major Component Control	Net Auxiliary Load (kWe)	0.60	50,700 – 73,500
12.6	Control Boards, Panels & Racks	Net Auxiliary Load (kWe)	0.60	50,700 – 73,500
12.7	Computer & Accessories	Net Auxiliary Load (kWe)	0.60	50,700 – 73,500
12.8	Instrument Wiring & Tubing	Net Auxiliary Load (kWe)	0.60	50,700 – 73,500
12.9	Other I & C Equipment	Net Auxiliary Load (kWe)	0.60	50,700 – 73,500

Exhibit 2-42 Scaling parameters and exponents for categories 6-9: "Improvements to Site"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
13	IMPROVEMENTS TO SITE			
13.1	Site Preparation	Gross Total (kWe)	0.47	650,000 – 1,130,000
13.2	Site Improvements	Gross Total (kWe)	0.47	650,000 – 1,130,000
13.3	Site Facilities	Gross Total (kWe)	0.47	650,000 – 1,130,000

Exhibit 2-43 Scaling parameters and exponents for categories 6-9: "Buildings and Structures"

Account Number	Item Description	Parameter	Exponent	Range
Category		10	10	10
14	BUILDINGS & STRUCTURES			
14.1	Combustion Turbine Area	Gas Turbine Power, kWe	0.53	421,000 – 811,000
14.2	Steam Turbine Building	Steam Turbine Power, kWe	0.60	230,000 – 321,000
14.3	Administration Building	Gross Total (kWe)	0.34	650,000 – 1,130,000
14.4	Circulation Water Pumphouse	Circulating water flow rate, gpm	0.60[1]	125,000 – 294,000
14.5	Water Treatment Buildings	Circulating water flow rate, gpm	0.66	125,000 – 294,000
14.6	Machine Shop	Gross Total (kWe)	0.34	650,000 – 1,130,000
14.7	Warehouse	Gross Total (kWe)	0.34	650,000 – 1,130,000
14.8	Other Buildings & Structures	Gross Total (kWe)	0.34	650,000 – 1,130,000
14.9	Waste Treating Building & Str.	Gross Total (kWe)	0.34	650,000 – 1,130,000

[1] Natural gas, air-fired without CO_2 capture uses an exponent of 0.82.