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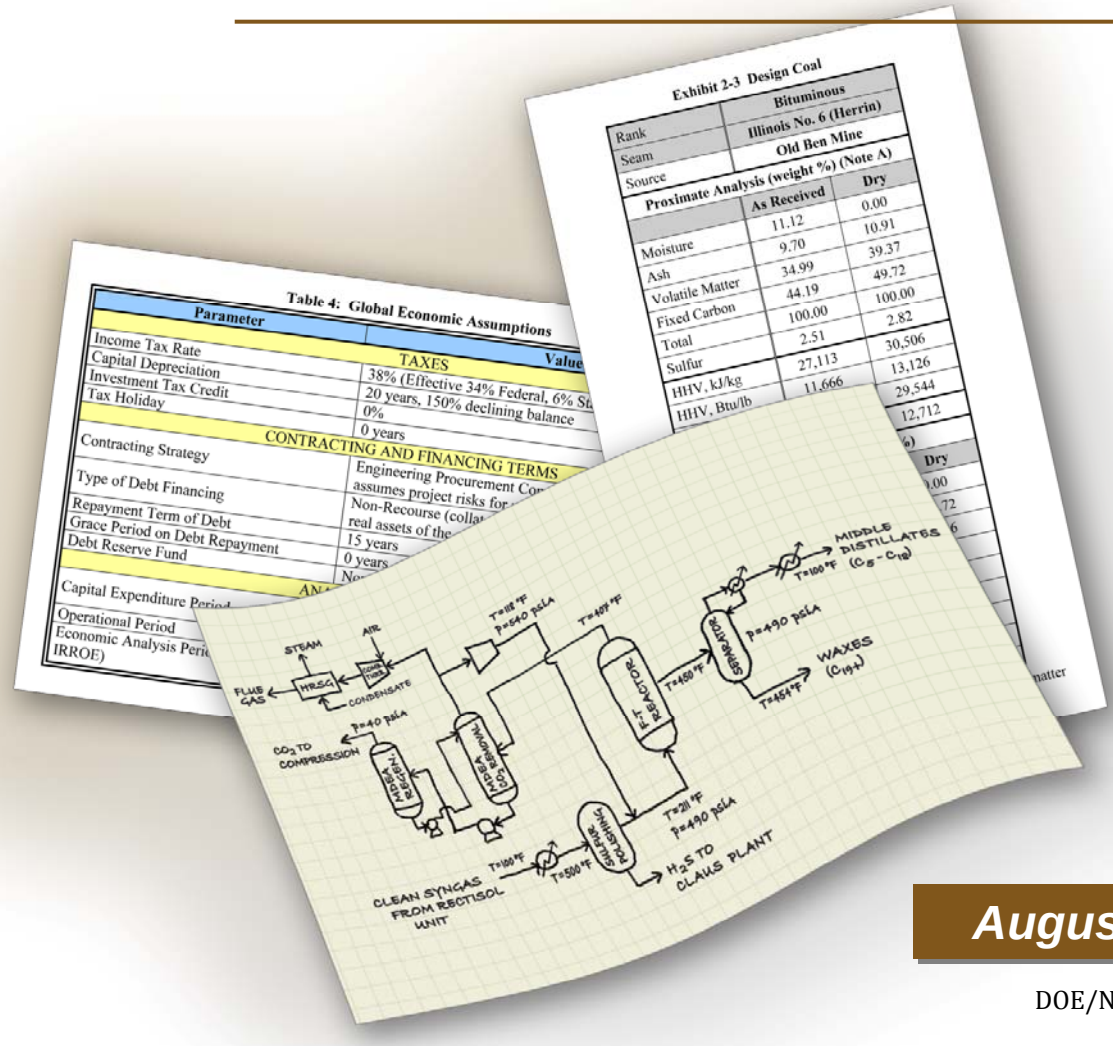
QUALITY GUIDELINES FOR ENERGY SYSTEM STUDIES

Estimating Plant Costs Using Retrofit Difficulty Factors



August 2013

DOE/NETL-341/082313

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DOE/NETL-341/082313

Final Report

August 23, 2013

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DOE Contract Number DE-FE0004001

Acknowledgments

This report was prepared by Energy Sector Planning and Analysis (ESPA) for the United States Department of Energy (DOE), National Energy Technology Laboratory (NETL). This work was completed under DOE NETL Contract Number DE-FE0004001. This work was performed under ESPA Task 341.03.03.

The authors wish to acknowledge the excellent guidance, contributions, and cooperation of the NETL staff, particularly:

Michael Matuszewski, NETL Technical Project Monitor

ESPA also wishes to acknowledge the valuable input provided by Lora Pinkerton and co-workers of WorleyParsons Group, Inc., but notes that this acknowledgement does not indicate their endorsement of the results.

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Exhibits

Acronyms and Abbreviations

AACE	Advancement of Cost Engineering International
BoP	Balance of plant
CO_2	Carbon dioxide
DOE	Department of Energy
FGD	Flue gas desulfurization
I&C	Instrumentation and control
ID	Induced draft
HGCU	Hot gas cleanup
HRSG	Heat recovery steam generator
NETL	National Energy Technology Laboratory
O&M	Operation and maintenance
PC	Pulverized coal
SCR	Selective catalytic reduction
TG	Turbine generator
TPC	Total plant cost

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1 Background

The National Energy Technology Laboratory (NETL) funds studies that consider both greenfield and retrofit applications of CO_2 capture technologies. The purpose of this document is to describe a general cost-estimating procedure for retrofit applications using post-combustion CO_2 capture as an example. As with any high-level factored cost-estimating approach, particular care and judgment should be exercised when applying the retrofit factors to the scaled equipment costs. The retrofit cost premium procedures are developed for a post-combustion solvent-based CO_2 capture retrofit and the associated cost accounts. These cost account adjustments form the basis for calculating a representative overall range for cost sensitivities for general retrofit project capital costs and for extrapolating comparable adjustments for other technologies or configurations. These factors represent a generic retrofit application adjustment for the lower 48 states, while site-specific, and project-specific requirements could result in significant deviations.

Overall, for most currently envisioned carbon capture and compression retrofits, the NETL-defined total plant cost that has a 1.10 retrofit difficulty factor applied captures the high range of the detailed retrofit premium, relative to the greenfield equivalent costs, which are described in these quality guidelines.

2 Post Combustion Capture Cost Estimation and Retrofit Adjustment Methodology

The retrofit factor methodology is a multi-step process that was developed using reference costs from the report "Updated Costs (June 2011 Basis) for Selected Bituminous Baseline Cases," [1] which is also described in the cost estimating QGESS document. [2] This methodology assumes that the retrofit is occurring at the generic Midwest location similar to the reference plant assumptions. A location-based labor factor can be applied to adjust the reference estimate if that assumption does not hold for a particular application. The location factors listed in the Retrofit Cost Analysis for Post-combustion CO_2 Capture [3] report account for different productivity and wages in different regions across the United States (U.S.).

2.1 Greenfield Cost Equivalent for Retrofit Equipment

The first step in determining the retrofit costs is to determine the greenfield cost equivalent of the retrofit equipment. Standard cost scaling techniques are used to estimate the cost of the new equipment, using the June 2011 Bituminous Baseline reference costs. The generalized scaling equation is

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

Where SC = greenfield equivalent of the scaled cost for the retrofit technology

RC = item Reference Cost

SP = process Scaling Parameter for the retrofit equipment

RP = process Reference Parameter for the reference plant equipment

Exp = scaling Exponent

Scaling exponents and process parameters for the reference cost estimate are provided in the report "Quality Guidelines for Energy System Studies: Capital Cost Scaling Methodology." [2] This greenfield equivalent cost is multiplied by a retrofit difficulty factor to account for the premium associated with installing this equipment at an existing plant.

The factored retrofit cost (RC) is calculated by multiplying the SC greenfield equivalent cost by the retrofit difficulty factor (RF):

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

2.2 Retrofit Difficulty Factors

The retrofit difficulty factors shown in Exhibit 2-1 are applied to the greenfield equivalent capture technology cost for only the new retrofit (not the existing plant) costs. These adjustments are displayed in this document, but were developed as part of a previous retrofit costing study. [3] For line-item accounts that were not specifically examined, the high end of the range is listed as "Not Applicable" (N/A) to indicate that sufficient data was not found at this stage to support a rigorous basis for extrapolating retrofit difficulty factors for the same or similar technologies. Continued refinement and additional line-item adjustments can be expected as more plants are retrofitted and data becomes available for further analysis.

Equipment and material scope adjustments represent the cost premium, addressing minor differences in equipment specifications, layout, duct routing, and items where additional complexity is likely to be encountered. These range from 1.00 to 1.25 applied to the greenfield equivalent cost of the new retrofit equipment.

Labor productivity adjustments account for productivity losses associated with working on an existing operating plant site in potentially highly congested areas, and with modifications and tie-in to existing equipment and/or systems. These range from 1.00 to 1.30 applied to the greenfield equivalent installation labor costs for the retrofit.

Engineering judgment should be used in choosing the applicability of these adjustment factors. One example of a cost account that has a dependency between the retrofit design and the retrofit difficulty factor is the stack account. For example, the factors presented here assume the stack, Account 7.4, would be upgraded, as opposed to replaced. Replacing the stack should have a lower retrofit difficulty factor because there is less complexity and integration with the existing

equipment, although the total cost will be higher. For the typical level of detail, starting with the high range of the factor will help bound the major economic results, but selecting a more refined factor becomes important if the study is attempting to specifically optimize that decision.

Engineering judgment can be used to extrapolate the retrofit difficulty factor to similar types of equipment (for example, letdown turbine costs are grouped with the CO_2 compression account) and for selecting the applicability and specific factor within the range.

As an example of the effects of cost accounting, line-item categorization and the need to extrapolate line-item retrofit factors to other configurations, the ID booster fans are part of the equipment scope included in the 5B.1 CO_2 Removal System account. If ID fans were to be replaced and included in Account 4.4 Boiler BoP (listed as N/A), a high range needs to be established; Account 7.3 Ductwork or Account 9.1 Cooling Tower [fans] include similar equipment, which provide a basis for extrapolating a high range retrofit factor of 1.05-1.10 for equipment and 1.15-1.20 for labor (note that this range includes the retrofit difficulty adjustment assigned for Account 5B.1).

In general, the cost of equipment manufacture and delivery to the site tends to have a smaller premium compared to the labor productivity, which can significantly vary depending on the access to, and integration within, the plant.

Exhibit 2-1 Line-item Retrofit Difficulty Factors

		Retrofit Difficulty Factor			
	Cost Category	Equipment/Material		Labor Productivity	
		Low	High	Low	High
1	COAL & SORBENT HANDLING				
1.1	Coal Receive & Unload	1.00	N/A	1.00	N/A
1.2	Coal Stackout & Reclaim	1.00	N/A	1.00	N/A
1.3	Coal Conveyors	1.00	N/A	1.00	N/A
1.4	Other Coal Handling	1.00	N/A	1.00	N/A
1.5	Sorbent Receive & Unload	1.00	N/A	1.00	N/A
1.6	Sorbent Stackout & Reclaim	1.00	N/A	1.00	N/A
1.7	Sorbent Conveyors	1.00	N/A	1.00	N/A
1.8	Other Sorbent Handling	1.00	N/A	1.00	N/A
1.9	Coal & Sorbent Handling & Foundations	1.00	N/A	1.00	N/A
2	COAL & SORBENT PREP & FEED				
2.1	Coal Crushing & Drying	1.00	N/A	1.00	N/A
2.2	Coal Conveyor to Storage	1.00	N/A	1.00	N/A
2.3	Coal Injection System	1.00	N/A	1.00	N/A
2.4	Misc. Coal Prep & Feed	1.00	N/A	1.00	N/A
2.5	Sorbent Prep Equipment	1.00	N/A	1.00	N/A
2.6	Sorbent Storage & Feed	1.00	N/A	1.00	N/A
2.7	Sorbent Injection System	1.00	N/A	1.00	N/A
2.8	Booster Air Supply System	1.00	N/A	1.00	N/A
2.9	Coal & Sorbent Feed Foundation	1.00	N/A	1.00	N/A
3	FEEDWATER & MISC. BOP SYSTEMS				
3.1	Feedwater System	1.00	N/A	1.00	N/A
3.2	Water Makeup & Pretreating	1.00	1.05	1.05	1.25
3.3	Other Feedwater Subsystems	1.00	N/A	1.00	N/A
3.4	Service Water Systems	1.00	1.05	1.05	1.25
3.5	Other Boiler Plant Systems	1.00	N/A	1.00	N/A
3.6	FO Supply Sys & Nat Gas	1.00	N/A	1.00	N/A

3.7	Waste Treatment Equipment	1.00	1.05	1.05	1.25
3.8	Misc. Equip. (cranes, AirComp., Comm.)	1.00	1.05	1.05	1.25
4	PC BOILER				
4.1	PC Boiler & Accessories	1.00	N/A	1.00	N/A
4.2	SCR (w/4.1)	1.00	N/A	1.00	N/A
4.3	Open	1.00	N/A	1.00	N/A
4.4	Boiler BoP (w/ ID Fans)	1.00	N/A	1.00	N/A
4.5	Primary Air System	1.00	N/A	1.00	N/A
4.6	Secondary Air System	1.00	N/A	1.00	N/A
4.8	Major Component Rigging	1.00	N/A	1.00	N/A
4.9	Boiler Foundations	1.00	N/A	1.00	N/A
5	FLUE GAS CLEANUP				
5.1	Absorber Vessels & Accessories	1.00	N/A	1.00	N/A
5.2	Other FGD	1.00	N/A	1.00	N/A
5.3	Bag House & Accessories	1.00	N/A	1.00	N/A
5.4	Other Particulate Removal Materials	1.00	N/A	1.00	N/A
5.5	Gypsum Dewatering System	1.00	N/A	1.00	N/A
5.6	Mercury Removal System	1.00	N/A	1.00	N/A
5.9	Open	1.00	N/A	1.00	N/A
5B	CO_2 Removal & Compression				
5B.1	CO_2 Removal System	1.00	1.05	1.00	1.15
5B.2	CO_2 Compression & Drying	1.00	1.00	1.00	1.15
5B.3	CO_2 Removal System Letdown Turbine	1.00	1.00	1.00	1.15
6	COMBUSTION TURBINE/ACCESSORIES				
6.1	Combustion Turbine Generator	1.00	N/A	1.00	N/A
6.2	Open	1.00	N/A	1.00	N/A
6.3	Compressed Air Piping	1.00	N/A	1.00	N/A
6.9	Combustion Turbine Foundations	1.00	N/A	1.00	N/A

7	HRSG, DUCTING & STACK				
7.1	Heat Recovery Steam Generator	1.00	N/A	1.00	N/A
7.2	HRSG Accessories	1.00	N/A	1.00	N/A
7.3	Ductwork	1.00	1.10	1.05	1.20
7.4	Stack	1.00	1.25	1.00	1.30
7.9	Duct & Stack Foundations	1.00	1.10	1.00	1.25
8	STEAM TURBINE GENERATOR				
8.1	Steam TG & Accessories	1.00	N/A	1.00	N/A
8.2	Turbine Plant Auxiliaries	1.00	N/A	1.00	N/A
8.3	Condenser & Auxiliaries	1.00	N/A	1.00	N/A
8.4	Steam Piping	1.00	1.10	1.05	1.25
8.9	TG Foundations	1.00	N/A	1.00	N/A
9	COOLING WATER SYSTEM				
9.1	Cooling Towers	1.00	1.05	1.00	1.15
9.2	Circulating Water Pumps	1.00	1.05	1.00	1.15
9.3	Circ. Water System Auxiliaries	1.00	1.05	1.00	1.15
9.4	Circ. Water Piping	1.00	1.10	1.00	1.15
9.5	Make-up Water System	1.00	1.10	1.00	1.15
9.6	Component Cooling Water Sys	1.00	1.05	1.00	1.15
9.9	Circ. Water System Foundations & Structures	1.00	1.10	1.00	1.15
10	ASH/SPENT SORBENT HANDLING SYS				
10.1	Ash Coolers	1.00	N/A	1.00	N/A
10.2	Cyclone Ash Letdown	1.00	N/A	1.00	N/A
10.3	HGCU Ash Letdown	1.00	N/A	1.00	N/A
10.4	High Temperature Ash Piping	1.00	N/A	1.00	N/A
10.5	Other Ash Recovery Equipment	1.00	N/A	1.00	N/A
10.6	Ash Storage Silos	1.00	N/A	1.00	N/A
10.7	Ash Transport & Feed Equipment	1.00	N/A	1.00	N/A
10.8	Misc. Ash Handling Equipment	1.00	N/A	1.00	N/A
10.9	Ash/Spent Sorbent Foundation	1.00	N/A	1.00	N/A

11	ACCESSORY ELECTRIC PLANT				
11.1	Generator Equipment	1.00	N/A	1.00	N/A
11.2	Station Service Equipment	1.00	1.05	1.00	1.15
11.3	Switchgear & Motor Control	1.00	1.05	1.00	1.15
11.4	Conduit & Cable Tray	1.00	1.10	1.00	1.15
11.5	Wire & Cable	1.00	1.10	1.00	1.15
11.6	Protective Equipment	1.00	1.05	1.00	1.15
11.7	Standby Equipment	1.00	1.05	1.00	1.15
11.8	Main Power Transformers	1.00	1.05	1.00	1.15
11.9	Electrical Foundations	1.00	1.10	1.00	1.15
12	INSTRUMENTATION & CONTROL				
12.1	PC Control Equipment	1.00	N/A	1.00	N/A
12.2	Combustion Turbine Control	1.00	N/A	1.00	N/A
12.3	Steam Turbine Control	1.00	N/A	1.00	N/A
12.4	Other Major Component Control	1.00	N/A	1.00	N/A
12.5	Signal Processing Equipment	1.00	N/A	1.00	N/A
12.6	Control Boards, Panels & Racks	1.00	1.05	1.00	1.15
12.7	Distributed Control System Equipment	1.00	1.05	1.10	1.30
12.8	Instrument Wiring & Tubing	1.00	1.05	1.05	1.20
12.9	Other I & C Equipment	1.00	1.05	1.05	1.20
13	IMPROVEMENTS TO SITE				
13.1	Site Preparation	1.00	1.05	1.00	1.20
13.2	Site Improvements	1.00	1.05	1.00	1.20
13.3	Site Facilities	1.00	1.05	1.00	1.20
14	BUILDINGS & STRUCTURES				
14.1	Boiler Building	1.00	N/A	1.00	N/A
14.2	Turbine Building	1.00	N/A	1.00	N/A
14.3	Administration Building	1.00	N/A	1.00	N/A
14.4	Circulation Water Pumphouse	1.00	1.05	1.00	1.15

14.5	Water Treatment Buildings	1.00	1.05	1.05	1.25
14.6	Machine Shop	1.00	N/A	1.00	N/A
14.7	Warehouse	1.00	N/A	1.00	N/A
14.8	Other Buildings & Structures	1.00	1.05	1.00	1.15
14.9	Waste Treating Building & Structures	1.00	1.05	1.05	1.25

2.3 Operation and Maintenance Costs

Operation and maintenance (O&M) costs should acknowledge the continued operation of the existing plant for items such as property taxes and insurance, labor, maintenance, and continuing consumables. Pre-retrofit O&M costs are assumed to continue and be unchanged, contributing to the total post-retrofit O&M costs. As a simplifying assumption, property taxes and insurance costs increase as a percentage of the new retrofit equipment. The owner's costs should only consider the preproduction costs and inventory capital for the new equipment and the marginal increase in consumables. This makes the assumption that the plant already has the required fuel, consumables, and waste disposal to continue operating, regardless of whether the retrofit occurs; only increased consumables such as water usage or additional solvents, membranes, or sorbents and O&M costs for the new retrofit equipment need to be considered as additional owner's costs.

3 Retrofit Premium Procedure Using Retrofit Difficulty Factors

The retrofit difficulty factors are applied to establish equivalent greenfield costs for the required retrofit equipment. The equivalent greenfield costs can be established through several methods: the simplest is by applying linear point scope factors, which are plant-size and technology dependent, relating the cost of retrofitting a technology with the existing plant's cost or an analogous greenfield plant's cost; the recommended approach, described above, is to use exponent scaling from greenfield reference costs to account for economies of scale; more in-depth equivalent greenfield costs can be estimated using a full bottoms-up estimate of all equipment, which would also be an acceptable starting point for applying the retrofit difficulty factors. Once the greenfield equivalent cost for each newly retrofitted unit operation is established, the total retrofit cost, including the difficulty premium, can be directly calculated by applying the selected factors shown in Exhibit 2-1. If the technologies or cost accounting varies from the format presented below, engineering judgment can be used to map reasonable analogues or an overall capital cost sensitivity.

The retrofit difficulty factor calculation procedure is summarized in the following steps:

1. Start with the greenfield-equivalent cost of the required retrofit equipment and modifications (See Section 2.1 for exponent scaling cost estimation). For a listing of NETL-recommended capital costs, please refer to the NETL report, "*Updated Costs (June 2011 Basis) for Selected Bituminous Baseline Cases*".
2. Multiply each element of the entire capital cost breakdown in each line-item (equipment, material, direct, and indirect labor) by the corresponding retrofit difficulty factor for that element and account (See Exhibit 2-1)

3. Calculate the new cost for professional services (engineering, construction management, home office and fee) and contingencies (maintaining the same percentage of bare erected cost as used for greenfield estimates)
4. Sum the costs to calculate the total plant cost
5. Calculate O&M costs and owner's costs from the greenfield-equivalent cost, which does not change with retrofit difficulty, once the equipment is installed. For NETL-recommended methodology for calculating owner's costs, please see the NETL report, "*QGESS: Cost Estimation Methodology for NETL Assessments of Power Plant Performance*".

The above methodology captures economies of scale (via exponent scaling), based on selected design parameters for only the required retrofit equipment and modifications (to establish the greenfield equivalent costs), while bounding the typical retrofit difficulty.

4 Considerations for General Application

4.1 Extrapolating Line-item Cost Accounts

The line-item retrofit factors are general guidelines for informing typical variation in retrofit costs based on past quotes, cost estimating experience, and engineering judgment. For other technologies that have different equipment, either categorized under the same line-item accounts or for entirely different accounts, the established retrofit factors can be extrapolated based on similarity of equipment and/or interface with the existing plant. Select cost accounts, which may be of particular use for extrapolating to other technologies, are sorted by magnitude of the high end of the retrofit factor range for comparison in Exhibit 4-1. Accounts with larger retrofit factors are shaded with darker colors.

For example, a membrane system might use the Account 5B.2 CO_2 Compression & Drying retrofit factor as an analogue and starting point for estimating the cost of the compressors that provide the driving force for the membrane separation. In this example, the ducting to bring the flue gas to the compressor may have a larger retrofit factor due to brownfield considerations (reflected in the higher Account 7.3 Ductwork retrofit factor), but the compressors have minimal connection to the existing infrastructure. The other connections are mainly electrical, which keeps the labor productivity factor low, and the units are generally more modular and are delivered ready to the site, which minimizes the equipment premium.

Exhibit 4-1 Varying Magnitude of Retrofit Difficulty Factors for Notable Accounts

Cost Category		Retrofit Difficulty Factor			
		Equipment/Material		Labor Productivity	
		Low	High	Low	High
5B.2	CO_2 Compression & Drying	1.00	1.00	1.00	1.15
5B.3	CO_2 Removal System Letdown Turbine	1.00	1.00	1.00	1.15
5B.1	CO_2 Removal System	1.00	1.05	1.00	1.15
9.1	Cooling Towers	1.00	1.05	1.00	1.15
9.2	Circulating Water Pumps	1.00	1.05	1.00	1.15
11.2	Station Service Equipment	1.00	1.05	1.00	1.15
11.8	Main Power Transformers	1.00	1.05	1.00	1.15
12.6	Control Boards, Panels & Racks	1.00	1.05	1.00	1.15
14.4	Circulation Water Pumphouse	1.00	1.05	1.00	1.15
14.8	Other Buildings & Structures	1.00	1.05	1.00	1.15
12.8	Instrument Wiring & Tubing	1.00	1.05	1.00	1.20
13.1	Site Preparation	1.00	1.05	1.00	1.20
13.2	Site Improvements	1.00	1.05	1.00	1.20
13.3	Site Facilities	1.00	1.05	1.00	1.20
3.2	Water Makeup & Pretreating	1.00	1.05	1.00	1.25
3.7	Waste Treatment Equipment	1.00	1.05	1.00	1.25
14.5	Water Treatment Buildings	1.00	1.05	1.00	1.25
14.9	Waste Treating Building & Str.	1.00	1.05	1.00	1.25
9.4	Circ. Water Piping	1.00	1.10	1.00	1.15
9.5	Make-up Water System	1.00	1.10	1.00	1.15
9.9	Circ. Water System Foundations & Structures	1.00	1.10	1.00	1.15
11.4	Conduit & Cable Tray	1.00	1.10	1.00	1.15
11.5	Wire & Cable	1.00	1.10	1.00	1.15
11.9	Electrical Foundations	1.00	1.10	1.00	1.15
7.3	Ductwork	1.00	1.10	1.00	1.20
7.9	Duct & Stack Foundations	1.00	1.10	1.00	1.25
8.4	Steam Piping	1.00	1.10	1.00	1.25
7.4	Stack	1.00	1.25	1.00	1.30

The goal in selecting similar accounts to extrapolate costs to other technologies and accounting frameworks is to maintain comparability, and not to bias any specific technology being evaluated, while at the same time acknowledging and beginning to quantify the added costs associated with working at a brownfield site.

4.2 Cost Estimating Limitations

Particular care must be taken when estimating costs, especially as the project and site conditions deviate more from the reference cost conditions. These factors do not replace the detailed engineering that is required for more precise cost estimates. These factors were developed for the monoethanolamine (MEA) CO_2 capture technology using cost databases of similar absorber analogues, and the ranges are not validated for other technologies. Within the typical accuracy of NETL systems studies, these factors should be able to generalize to different solvent-based absorption systems (advanced amine systems), which have similar liquid pumping and handling and use of steam for solvent stripping, to different steam cycles, whose premium is captured in the reference plant estimate. It should be made clear, in reports where these factors are being used, that their use changes the level of the cost estimation accuracy from the typical low end of the Advancement of Cost Engineering International (AACE) Class 4 confidence interval of +30 percent/-15 percent towards higher uncertainty.

These factored cost estimating approaches are most useful for carefully controlled comparisons by unbiased parties with significant experience, or history with cost estimating, and the specific cost estimates around which these factors were developed.

4.3 Simplified Total Plant Cost Multiplier

A simplified single overall factor provides perspective for these retrofit difficulty assumptions for a capital cost sensitivity (on summed total plant cost [TPC] basis). The incremental retrofit difficulty factors, using the high value applied to a retrofit of an existing subcritical PC plant, has a weighted average retrofit total plant cost premium of 1.10, as defined in the cost estimating QGESS [2], and shown in Exhibit 4-2. [4] For a plant with less complex equipment, such as an existing NGCC plant, this weighted average TPC multiplier is approximately equal, but applied to a lower total plant cost. [5]

Exhibit 4-2 Weighted Average Retrofit Factor for Examined Technologies

Case Technology Retrofit	Weighted Average TPC Retrofit Factor
Existing PC Plant – PCC Retrofit	1.10
Existing NGCC Plant – PCC Retrofit	1.09
Generic Plant / Technology Recommendation	1.10

Instead of a line-by-line analysis by cost account with the multi-factor approach, this average retrofit premium isolates the cost premium for retrofit projects; for example, one could say that

$100 of installed greenfield equipment tends to cost $110 if installed as a retrofit. This approach also lends itself to a simple sensitivity analysis on a single retrofit factor that would provide reasonable estimates of the impact of retrofitting. Another benefit is that this avoids creating a set of accounting rules that can be gamed to bias the cost estimate. This simplified multiplier compartmentalizes the required cost estimating and engineering judgment knowledge requirements in selecting the most applicable or representative retrofit factor and resulting retrofit costs, but also helps bound the typical effects associated with retrofit construction with minimal additional work. A TPC retrofit factor range of 1 to 1.25, the maximum single account level difficulty factor, bounds a useful range of potential retrofit difficulties and should be presented as part of the standard capital cost sensitivity analysis.

References

1 The National Energy Technology Laboratory (NETL). (October 2012). Updated Costs (June 2011 Basis) for Selected Bituminous Baseline Cases. Pittsburgh, Pennsylvania.

2 The National Energy Technology Laboratory (NETL). (April 2011). QGESS: Cost Estimation Methodology for NETL Assessments of Power Plant Performance. Pittsburgh, Pennsylvania.

3 The National Energy Technology Laboratory (NETL). (December 2011). Retrofit Cost Analysis for Post-combustion CO2 Capture. Pittsburgh, Pennsylvania.

4 The National Energy Technology Laboratory (NETL). (January 2013). Post-Combustion Capture Retrofit Study Update. Pittsburgh, Pennsylvania.

5 The National Energy Technology Laboratory (NETL). (April 2013). Cost and Performance of Retrofitting NGCC Units for Carbon Capture. Pittsburgh, Pennsylvania.