Chapter 2

Cost Estimation: Concepts and Methodology

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used.[2] Texas accepts the Manual methodology "as a sound source for the quantitative cost analysis" for BACT analyses it reviews.[3]

The industrial user is more likely to have site-specific and detailed information than the average cost and sizing information used in a study estimate. The methodology laid out in this Manual can provide cost estimates that are more accurate when using detailed site-specific information. The anecdotal evidence from most testimonials volunteered by industrial users indicates that much greater accuracy than 30 percent probable error can be attained. However, this Manual does not assume that detailed site-specific information will always be available to estimate costs associated with installing and operating pollution abatement equipment at a much higher accuracy level. This Manual retains the conclusion that the cost methodology laid out in this chapter and information in each control measure chapter with 30% probable error is relevant to be used in air pollution control cost estimation for permitting actions. It is the affected industry source that bears the burden of providing information of sufficient quality that will yield cost estimates of at least a study-level estimate for permitting decisions pertaining to their facilities.

2.4 Cost Categories Defined

The terminology addressing cost categories used in the earlier editions of this Manual was adapted from the AACEI. [2]. However, different disciplines give different names to the same cost components, and the objective of this edition is to reach out to a broader scientific audience. For example, engineers determine a series of equal payments over a long period of time that fully funds a capital project (and its operations and maintenance) by multiplying the present value of those costs by a capital recovery factor, which produces an Equivalent Uniform Annual Cost (EUAC) value. This is identical to the process used by accountants and financial analysts, who adjust the present value of the project's cash flows to derive an annualized cost number.

2.4.1 Elements of Total Capital Investment

In assessing the total capital investment, this Manual takes the viewpoint of an owner, the firms making the investment, or those who have material interest in the project. Total capital investment (TCI) includes all costs required to purchase equipment needed for the control system (purchased equipment costs), the costs of labor and materials for installing that equipment (direct installation costs), costs for site preparation and buildings, and certain other costs (indirect installation costs). TCI also includes costs for land, working capital, and off-site facilities.[4] Taxes, permitting costs, and other administrative costs are covered in Section 2.6.5.8. Financing costs

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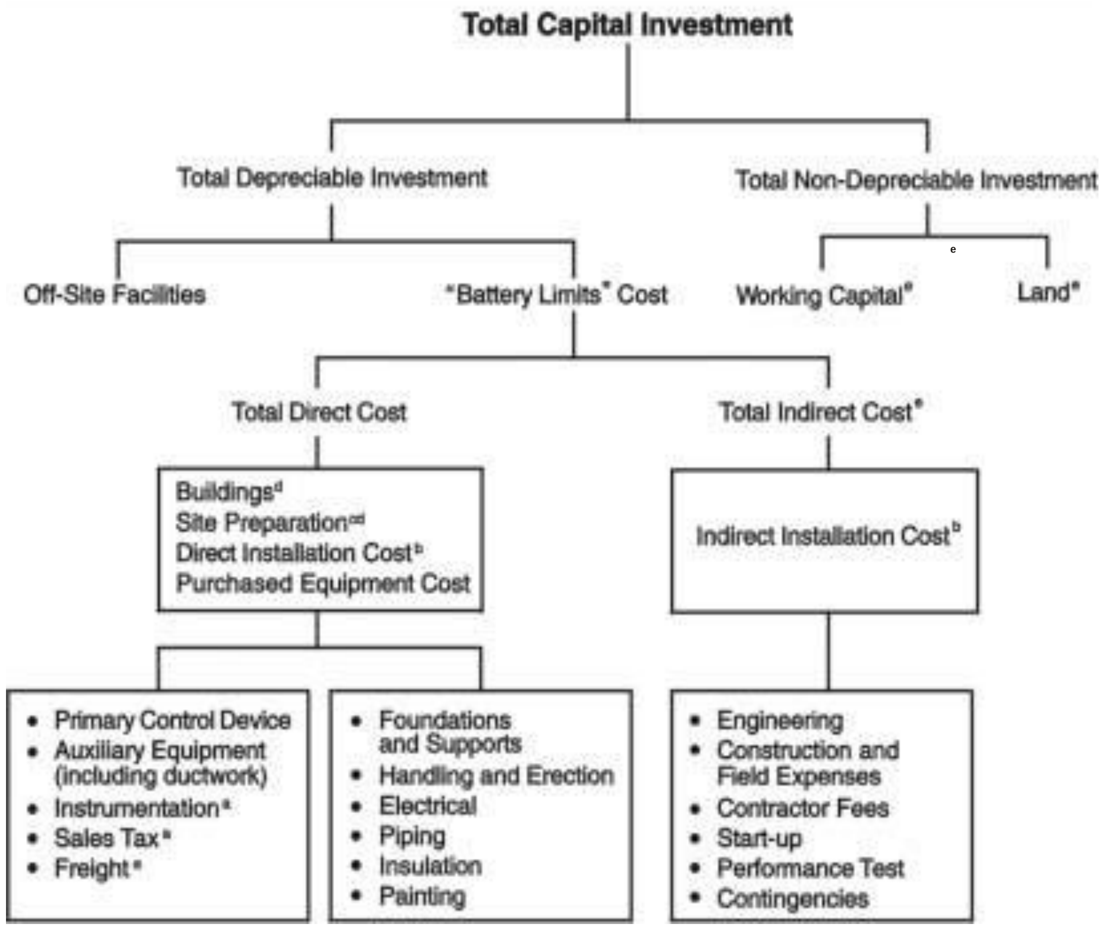
[2] State of Virginia, Department of Environmental Quality. Draft PSD Guidelines, August 4, 2011. Pp. 4-4 to 4-5.
[3] Texas Commission on Environmental Quality. Air Permits Division. Air Permit Reviewer Reference Guide, APDG 6110. Appendix G. p. 45. January 2011.
[4] Estimates of TCI for some control measures may not necessarily be calculated in this way due to availability of public information on capital investment costs and equations for those measures, such as the SNCR and SCR chapters in this Manual.

are covered in Sections 2.5.3 and 2.5.4. Foregone revenue associated with facility shut downs are covered in Section 2.6.4.2.

Direct installation costs include costs for foundations and supports, erecting and handling the equipment, electrical work, piping, insulation, and painting. Indirect installation costs include such costs as engineering costs; construction and field expenses (i.e., costs for construction supervisory personnel, office personnel, rental of temporary offices, etc.); contractor fees (for construction and engineering firms involved in the project); start-up and performance test costs (to get the control system running and to verify that it meets performance guarantees); and contingencies. Another item within owner's costs, technology royalties, is not separately included with the Manual's methodology because technology royalties are assumed to be reflected within the purchased equipment costs. Contingencies is a catch-all category that covers unforeseen costs that may arise, such as "… possible redesign and modification of equipment, escalation increases in cost of equipment, increases in field labor costs, and delays encountered in start-up." [2] Contingencies are discussed in more detail later in this chapter. Contingencies are not the same thing as uncertainty and retrofit factor costs, which are treated separately in this chapter. Escalation is not treated as part of contingencies. Please refer to section 2.6.4 for further discussion.

The elements of TCI are displayed in Figure 2.2. Note that the sum of the purchased equipment cost, direct and indirect installation costs, site preparation, and buildings costs comprises the battery limits estimate. A battery limit is the geographic boundary defining the coverage of a specific project [3]. Usually this encompasses all equipment of interest (in this case, the pollution control equipment), but excluding provision of storage, utilities, administrative buildings, or auxiliary facilities unless so specified [3]. This estimate would mainly apply to control systems installed in existing plants, though it could also apply to those systems installed in new plants when no special facilities for supporting the control system (i.e., off-site facilities) would be required. Off-site facilities include units to produce steam, electricity, and treated water; laboratory buildings; and railroad spurs, roads, and other transportation infrastructure items. Some pollution control systems do not generally have off-site capital units dedicated to them since these pollution control devices rarely consume energy at that level. However, it may be necessary—especially in the case of control systems installed in new or "grass roots" plants—for extra capacity to be built into the site generating plant to service the system. For example, installation of a venturi scrubber, which often requires large amounts of electricity, would require including costs associated with off-site facilities.

Note, however, that the capital cost of a device does not include routine utility costs (which can include the cost of steam, electricity, process and cooling water, compressed air, refrigeration, waste treatment and disposal, and fuel), even if the device were to require an offsite facility. Utility costs are categorized as operating costs that covers both the investment and operating and maintenance costs for the utility. The utility costs associated with start-up operations are included in the "Start-Up" component of the indirect installation costs. Operating costs are discussed in greater detail below. In addition, not every air pollution control system installation will have all of the elements for its TCI that are listed below (e.g., buildings).



[a]Typically factored from the sum of the primary control device and auxiliary equipment costs.
[b]Typically factored from the purchases equipment cost.
[c]Usually required only at "grass roots" installations.
[d]Unlike the other direct and indirect costs, costs for these items usually are not factored from the purchased equipment cost. Rather, they are sized and costed separately.
[e]Normally not required with add-on control systems.

Figure 2.2: Elements of Total Capital Investment

As Figure 2.2 shows, the installation of pollution control equipment may also require land, but since some add-on control systems take up very little space (often a quarter-acre or less), this cost may be relatively small. Certain control systems, such as those used for flue gas desulfurization (FGD) or selective catalytic reduction (SCR), require larger quantities of land for the equipment, chemicals storage, and waste disposal. In these cases, especially when performing a retrofit installation, space constraints can significantly influence the cost of installation, and the purchase of additional land and remediation of existing land and property may be a significant factor in the development of the project's capital costs.

However, land is not treated the same as other capital investments, since it is not depreciated for accounting purposes. The value of the land may fluctuate depending on the market conditions, but for accounting purposes and assessing private costs, land is not depreciated. The purchase price of new land needed for siting a pollution control device can be added to the TCI, but it must not be depreciated. If the firm plans on dismantling the device at some future time, the value of the land should be included at the disposal point as an "income" to the project to net it out of the cash flow analysis (more on cash flow analysis later, in section 2.5.4).

One might expect initial operational costs (the initial costs of fuel, chemicals, and other materials, as well as labor and maintenance related to start-up) to be included in the operating cost section of the cost analysis instead of in the capital component, but such an allocation would be inappropriate. Routine operation of the control does not begin until the system has been tested, balanced, and adjusted to work within its design parameters. Until then, all utilities consumed, all labor expended, and all maintenance and repairs performed are a part of the construction phase of the project and are included in the TCI in the "Start-Up" component of the indirect installation costs.

In addition, the TCI of controls for sources that affect fan capacity (e.g., FGD scrubbers, SCRs) may be impacted by the unit's elevation with respect to sea level. Cost calculations for the control measures within the Manual have typically been developed for systems located at sea level. For systems located at higher elevations (generally over 500 feet above sea level), the purchased equipment cost and balance of plant cost should be increased based on the ratio of the atmospheric pressure between sea level and the location of the system, i.e., atmospheric pressure at sea level divided by atmospheric pressure at the elevation of the unit.[5]

The method for estimating TCI in this Manual is an "overnight" estimation method. This method estimates capital cost as if no interest was incurred during construction and therefore estimates capital cost as if the project is completed "overnight." An alternate way of describing this method is the present value cost that would have to be paid as a lump sum up front to completely pay for a construction project. Cost items such as Allowance for Funds Used During Construction (AFUDC), which is defined as the costs of debt and equity funds used to finance plant construction, and is an amount credited on the firm's statement of income and charged to construction in progress on the firm's balance sheet, is treated separately in Section 2.5.3 in this Manual. This item is an estimate that is incurred over the timespan of construction. For example, this is considered as a cost item within the electric power industry.[6] [15] Other cost items similarly treated separately include escalation of costs to a future year due to inflation in Section 2.5.4. We provide more discussion later in this chapter on these cost items that are not included in this section.

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[5] One instance of this is the estimates of costs for the recently revised SNCR and SCR Control Cost Manual chapters, which are available at http://www.epa.gov/ttn/ecas/costmodels.html.

[6] See the National Energy Technology Laboratory's "Quality Guidelines for Energy System Studies: Cost Estimation Methodology for NETL Assessments of Power Plant Performance."

2.4.2 Elements of Total Cost

Total Cost (TC) refers to costs that are incurred yearly. TC has three elements: direct costs (DC), indirect costs (IC), and recovery credits (RC), which are related by the following equation:

$$TC = DC + IC - RC \qquad (2.1)$$

The basis of direct costs and recovery credits is one year, as this period allows for seasonal variations in production (and emissions generation) and is directly usable in financial analyses. (See Section 2.3.) [4] The various annual costs and their interrelationships are displayed in Figure 2.3. Some indirect costs are not incurred on an annual basis. Purchase, installation, and start-up of pollution abatement capital equipment often take multiple years. To incorporate these multi-year costs with other annual costs, the capital costs are amortized and converted into capital recovery. If the timing between direct costs and indirect costs are different, then an alternative approach for estimating total cost is to calculate the present value of these costs before summing them.

Variable costs are those that vary with some measure of productivity - generally the company's productive output. But for our purposes, the proper metric may be the quantity of exhaust gas processed by the control system per unit time. Semi-variable costs also vary with some measure of production, but have a positive cost even when production is zero.

An example would be a boiler producing process steam for only sixteen hours a day. During the time the boiler is idle, it costs less to keep the boiler running at some idle level than to re-heat it at the beginning of the next shift. Consequently, that idle level operation cannot be attributed to production and should be considered the fixed component of the semi-variable fuel cost of the boiler. Direct costs include costs for raw materials (reagents or adsorbers), utilities (steam, electricity, process and cooling water), waste treatment and disposal, maintenance materials (greases and other lubricants, gaskets, and seals), replacement parts, and operating, supervisory, and maintenance labor. Generally, raw materials, utilities, and waste treatment and disposal are variable costs, but there is no hard and fast rule concerning any of the direct cost components. Each situation requires a certain level of insight and expertise on the part of the analyst to present the cost components accurately

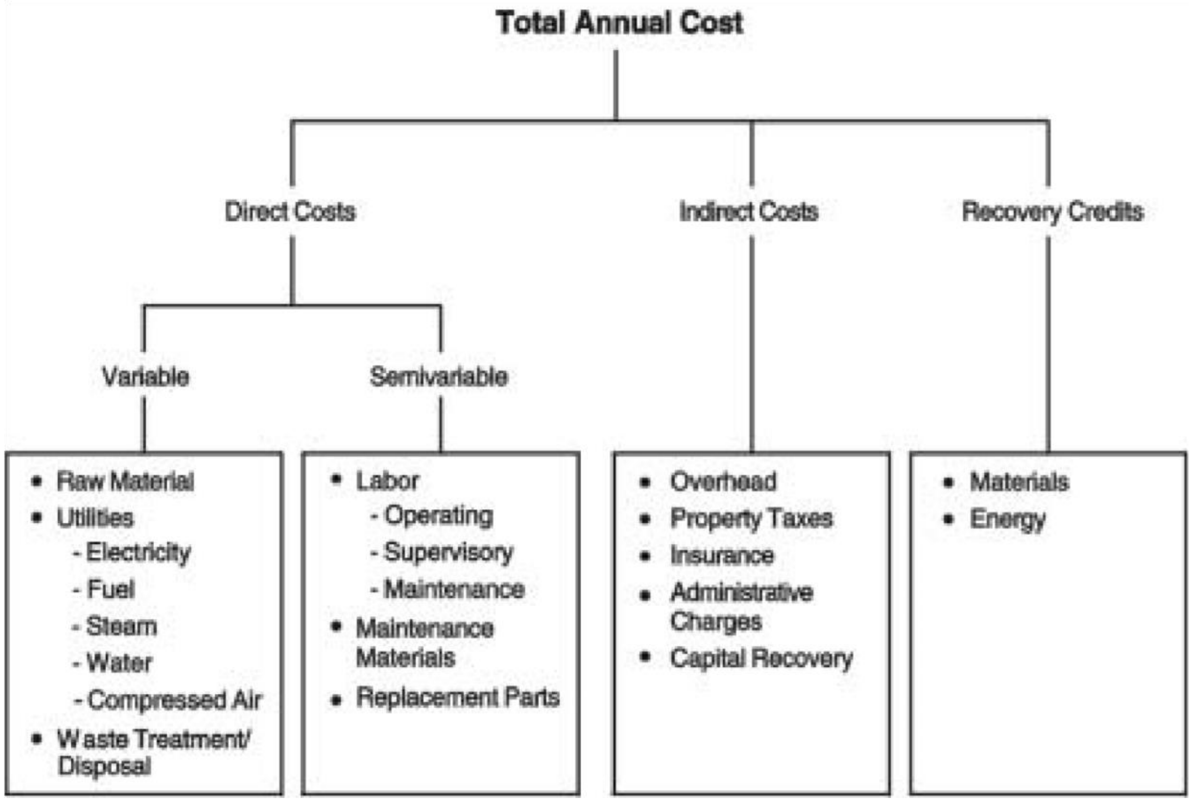

Figure 2.3: Elements of Total Annual Cost

Indirect, or "fixed" annual costs are independent of the level of production (or whatever unit of measure serves as the analytical metric) and, in fact, would be incurred even if the control system were shut down. Indirect costs include such categories as administrative charges, property taxes, insurance, administrative charges including permitting costs and capital cost amortized into capital recovery.

Capital is depreciable, indicating that, as the capital is used, it wears out and that lost value cannot be recovered. Economic depreciation, which is the lost value due to wear and tear, is different than accounting depreciation, the declared lost value, that is usually used in a cost analysis. Depreciation costs are a variable or semi-variable cost that is also included in the calculation of tax credits (if any) and depreciation allowances whenever taxes are considered in a cost analysis. However, taxes are not uniformly applied, and subsidies, tax moratoriums, and deferred tax opportunities distort how the direct application of a tax works.

Finally, direct and indirect annual costs can be offset by recovery credits, taken for materials or energy recovered by the control system, which may be sold, recycled to the process, or reused elsewhere at the site. An example of such credits is the by-product of controlling sulfur with a FGD scrubber. As the lime or limestone reagent reacts with the sulfur in the exhaust gas stream, it becomes transformed into $CaSO_4$ - gypsum - which can be landfilled inexpensively (a direct cost) or collected and sold to wallboard manufacturers (a recovery credit). These credits, must be calculated as net of any associated processing, storage, transportation, and any other costs required to make the recovered materials or energy reusable or resalable. Great care and judgment must be exercised in assigning values to recovery credits, since materials recovered may be of small quantity or of doubtful purity, resulting in their having less value than virgin material. Like direct annual costs, recovery credits are variable, in that their magnitude is directly proportional to level of production.

A more thorough description of these costs and how they may be estimated is provided in Section 2.6

2.5 Financial Concepts

Firms have latitude in developing compliance strategies. For standards that are performance oriented, firms have great latitude. Even for standards that are fairly prescriptive and technical in nature, firms still have to make some choices on how to comply. How do they compare these choices or alternatives?

Alternatives will usually have expenditures at multiple times. Not only may the expenditures be different but the timing of expenditures may also be different. When comparing two different investment opportunities, how do you distill all of these data into one comprehensive and coherent form so that an informed decision can be made? This section deals with a number of the concepts and operations that are needed to make a meaningful comparison. They include: selection of an appropriate timeframe, addressing the time value of money, adjusting for prices over time, and selection of the appropriate measure of cost.

2.5.1 Time Frame

To compare two alternatives in a meaningful way, the comparison is more meaningful when the alternatives are examined over the same time frame or calculate the net present value of the alternatives. For example, if one alternative uses a control device that lasts two years and another alternative uses a device that lasts three years, the alternatives may be difficult to compare directly because of the inconsistent lifetimes of the devices. One approach to developing a more meaningful comparison would be to assume a common time frame by using each type of device for six years, with the two-year alternative being replaced two times and the three-year alternative being replaced once. Another approach is to calculate the net present value of the two alternatives. Amortization or the EUAC method also can be helpful in comparing alternatives with different lifetimes.

2.5.2 Interest Rates

Firms may borrow to finance the expenses associated with their compliance strategies. The interest rate at which a firm borrows is a key component in estimating the total costs of compliance. Financial markets set different interest rates for different activities depending on many factors.