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Projections of Cost and On-Site Manual-Labor Requirements for Constructing Electric-Generating Plants, 1980-1990

February 1982

Construction Labor Demand System

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Preface

This report is an update of an earlier monograph Projections of Cost Duration, and On-Site Manual Labor Requirements for Constructing Electric Generating Plants, 1979-1983, DOE/IR-0 057 and DOL/CLDS/PP2, September 1979. These reports represent a continuing effort by the Federal Government to forecast the capital and labor required for constructing electric generating capacity additions necessary to accomodate projected economic and population growth in the United States and its regions.[1]

The analysis presented here was accomplished as part of the research program of the Construction Labor Demand System (CLDS). CLDS is a computerized management information system of the Department of Labor and is designed to forecast, on a short-term basis (5 years), construction labor demand by occupation at the regional and state levels.

The striking historical increases in capital cost and on-site manual labor requirements per kilowatt of new installed capacity shown in this report are cause for national concern. Although the possible causes of the increases, such as increasing environmental/safety regulations, suboptimal remaining sites, lower productivity, etc., are not treated in the analysis, the changes in cost and skill requirements presented in this study should be of substantial value to the utility industry, architectual and engineering design firms, constructors, unions, and government planners and policy makers.

The estimates of cost per KWe of installed capacity contained in this report differ from those contained in the 1979 CLDS forecasts (Projections of Cost, Duration, and On-Site Manual Labor Requirements For Constructing Electric Generating Plants, 1979-1983). The greatest difference is between the unit cost time series for fossil plants in the 1979 study and in this study. Although the earlier study used 1975 dollars while this study uses 1980 dollars, the former study estimated real unit costs to be about 20 percent higher than the latter primarily because of the use of different data bases. We believe the cost estimates included in this study to be the more accurate, because they are based upon carefully controlled cost data collected from the utility industry by CLDS, while the estimates included in the earlier study were based upon secondary, historical cost data aggregated by total facility (rather than generating unit) reported by the Federal Power Commission.

However, it should be noted that the estimates of capital costs for coal-fired plants were based upon responses to 71 cost questionnaires mailed to a population of over 200 base-load units with construction beginning in the 1970's. It is possible that the sample disproportionately consisted of low-cost units if the "successfully" constructed units were more likely to be represented than the "less successful" units. Therefore, the cost per KWe estimates shown in this report for coal plants should be interpreted as a lower (conservative) boundary; the upper boundary may be as much as 10 to 15 percent higher. (The above caveat is not relevant for nuclear plants, since the response sample of 103 units included all units in commercial operation in 1981, omitting the turnkey units.)

The historical labor requirement estimates for fossil and nuclear units in both studies are quite similar except that this study shows the impact of the accident at Three Mile Island on labor and capital requirements for nuclear powerplants.

A new and less optimistic forecast of growth in electrical demand became available from the Department of Energy after the first draft was prepared, and the final manuscript is based upon these lower growth estimates.

The research effort described in this report was jointly funded by the Office of Energy Research of the U. S. Department of Energy and the Employment Standards Administration of the U. S. Department of Labor. William F. Hahn, director of CLDS, U. S. Department of Labor, was responsible for the overall direction of the study. Roger L. Bowlby, Soon Paik, and William R. Schriver analyzed the data and wrote the report; computer applications were performed by Jason Kim and Scotty Bolling; research assistance was provided by Robert Osborne, Mark Warren and Nasser Vasegh-Daneshvary; James Rechnitzer conducted the data survey (OMB 1215-0086) and Wilma Gray typed the manuscript. Within the Department of Energy, Norman Seltzer, Chief of the Manpower Assessment Branch, Office of Energy Research, provided support and guidance in the development of the study.

The cooperation of the many utility companies that responded to the survey underlying this report is gratefully acknowledged. The assistance of John Rasmussen of the Edison Electric Institute (EEI) Construction Committee is particularly noted. Mr. Rasmussen, Carroll H. Dunn, Business Roundtable, Howard I. Bowers, Oak Ridge National Laboratory, Eric Haskins, Edison Electric Institute, and Robert Eynon and staff of the Department of Energy's Energy Information Administration also reviewed an early draft of the manuscript and their suggestions were used to revise the final report. The authors wish to express their gratitude for this assistance.

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An Overview

The four most significant trends disclosed in this study are: (1) regional shifts in construction labor associated with electric generating plants; (2) a path of erratic decline in this activity from 1980 to 1986, recovery between 1987 and 1989, and further decline in 1990, adding up to an aggregate decline from 1980 to 1990 equivalent to an annual compound rate of minus 2.1 percent; (3) a change in the relative importance of some major construction trades, with the largest declines for painters, truck drivers, cement masons and pipefitters, and increases for the boilermakers and asbestos workers required for powerplant construction; and (4) a substantial increase in real costs during the 1970's to construct new generating capacity.

Two regions are expected to experience gains between 1980 and 1990 in labor requirements associated with powerplant construction: New York-New Jersey and the Middle Atlantic regions. Eight of the 10 Federal regions are expected to be net losers of construction labor requirements, with the greatest losses in New England, the Great Plains, and the Pacific West (Arizona, California, Hawaii and Nevada).

While the Nation is projected to show a modest loss of 2.1 percent per year in labor requirements related to powerplant construction over the decade, labor requirements are expected to decrease quite precipitously by 33 percent between 1980 and 1986 before increasing by 13 percent from 1986 to 1990 when the demand for electricity is expected to begin outpacing existing generating capacity.

Two of the 15 trade categories analyzed are expected to show increases in demand for powerplant construction and thirteen are projected to decline. These changes are primarily results of shifts from nuclear to coal plants and the dominance of new initiations in the latter part of the decade and completions during the early part of the decade. Boilermakers and asbestos workers are expected to increase by 35 and 12 percent, respectively, while painters, truck drivers, and cement masons are projected to lose 39, 37, and 27 percent, respectively.

During the recent past, major increases in real capital costs and labor requirements per kilowatt of installed capacity have characterized expansions in electric generating capacity. Over the 11 year period from 1967 to 1978 real costs and workhour requirements for nuclear plants rose at a compound annual rate of about 10.5 and 7.8 percent, respectively. Real costs and workhour requirements for coal-fired plants increased at compound annual rates of about 5.4 and 4.8 percent, respectively, from 1972 to 1980.

It is assumed that changing environmental and safety regulations have been the dominant cause of past cost increases by adding to the scope and complexity ("ratcheting") of design and construction work. The continued imposition of new regulations also had the effect of diminishing the gains from learning as experience in design and construction accumulated. If the existing regulations have reached a point of stabilization (or even diminution) then it can be hoped that future costs will eventually stabilize in real terms. This optimistic position has been taken in the projections contained in this report but they are subject to the uncertainties of policy developments during the years to come.

I. Introduction

The objective of this study is to provide a consistent set of estimates, based upon year of start of construction, of capital costs and labor requirements for powerplant construction which can be used by the government, utilities, constructors, labor organizations, industry vendors, and the general public for policymaking and planning purposes. Separate projections for nuclear, hydroelectric, oil, gas, coal, and pump storage electric generating facilities are included. Within each category, estimates of on-site labor requirements are provided for 14 separate craft classifications for 10 geographic regions of the United States.

It should be noted that the estimates are based upon powerplants already under construction, those in advanced planning stages, and forecasted capacity additions which are expected to be under construction during the 1980-1990 interval. The estimates rely heavily upon a special survey of utilities conducted by the Department of Labor in 1981. To insure continued usefulness, the projections will be revised periodically to reflect new information and changing circumstances.

Forecasting regional or even National additions to capacity, most readers will agree, is a hazardous sport. Regulatory changes at the national and state levels, interest rate changes, and OPEC price changes coupled with conservation efforts of consumers (price elasticities in the market place) and shifts in the regional composition of economic and population growth complicate and destabilize investment decisions. Further complications arise when planned or in-progress construction is delayed, deferred or canceled --- all common occurrences during periods of escalating costs and dampening demand. (During the period this study was in preparation a deferment of in-progress nuclear construction was announced by the Tennessee Valley Authority, totaling 9968 MWe of capacity, and the Washington Public Power Supply System cancelled in-progress construction of 2458 MWe of nuclear capacity. If the 8 TVA units and 2 WPPSS units involved are ultimately abandoned, and there is a high probability this will be the case, it could result in historically unprecendented losses in sunk costs in the range of 15 to 20 billions of dollars).

The labor requirement forecasts can be no better than the forecast of construction schedules, but the former might also suffer from unpredictable changes in labor productivity and technology. Although great effort has been made to incorporate in this study the predictable influence of economic trends, unexplained variance is unavoidably present in any undertaking of this kind.

The need for the type of research reported in this study is quite apparent given the nation's energy demands and the substantial resource requirements associated with powerplant construction. A recent report issued by the Economic Policy Council of the United Nations Association of the United States of America recommended that the Federal Government give the highest priority to research in the field of energy-job relationships. "With each passing day it becomes apparent just how fundamental this subject is to our society and future."[2]

During the 1980-1990 period approximately 10 percent of the total workhours spent on all new construction will be devoted to powerplant construction alone. Since powerplants are frequently located in areas of low population density, they often dominate the local labor markets. Being able to anticipate even with a modest degree of accuracy the on-site labor requirements by occupation to construct a nominal facility may be of substantial advantage to those responsible for the assessment of economic impact, vocational training, and apprentice administration and officials of local and state government. The total regional labor demand created by powerplant construction is also of interest to the individual utilities, contractors, and unions who have a mutual interest in seeing that the construction jobs are efficiently staffed. The information provided in this report (in addition to the demand for the same occupations created by residential building construction, nonresidential building construction, nonbuilding construction, and other energy construction which is also available from CLDS at the state level)[3] can be a valuable aid in attempting to balance craft labor supply and demand at the regional level.

Since it may be of interest to utilities, design firms, and constructors to compare their estimates of costs and labor requirements for planned facilities with simulated estimates for nominal facilities based upon industry experience, we have included in this report capital cost (in constant 1980 dollars) and on-site manual labor requirements per installed kilowatt of capacity for nominal facilities by year of construction start. The nominal facilities are classified by fuel type, capacity size, and geographic location. The reader is cautioned that the nominal facility data were not intended to be used to estimate the cost or labor requirements of a specific powerplant. Such a procedure would be frought with pitfalls due to, among other things, the considerable variance that surrounds the base line estimate concept.

Part II contains an analysis of generating capacity additions by region and a description of how their cost and labor requirements were estimated. Part III provides an analysis of unit capital costs and unit labor requirements. Within Part IV are presented national and regional requirements of construction labor. Appendix A contains a technical description of the conceptual framework of the forecasting model and the econometric procedures used to estimate trend functions. Appendix B gives projected electric capacity additions through 1995 by region. Appendix C contains a projection of labor requirements associated with planned and in-progress construction (excluding forecasts) taken from Electrical World, January 1981. Appendix D presents a cash-flow method for converting constant dollars to current dollars and vice versa for coal-fired and nuclear powerplant construction. Appendix E provides a listing of data sources and references.

II. Electric Generating Capacity Additions and Associated Labor Requirements

Table 1 shows additions to electric generating capacity (including both capacity expansions and replacements) for six types of facility by years from 1980 to 1995 (regional capacity additions are shown in Appendix B.) The histogram in Figure 1 presents the same data. Capacity is counted in the table at the time it comes on line, so that projections to 1995 are necessary in order to capture labor demand during the late 1980's and 1990.

The capacity additions are subdivided into "planned"

Table 1

Electric Generating Capacity Additions[a] in the United States
by Fuel-Type, 1980-1995
(Megawatts)

Type		80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	P	3991 (4)	14264 (13)	14021 (13)	11263 (11)	6761 (6)	10477 (9)	5472 (5)	4345 (4)	933 (1)	2187 (2)	3687 (3)	2430 (2)	3687 (3)	1120 (1)	1120 (1)	-
	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	T	3991 (4)	14264 (13)	14021 (13)	11263 (11)	6761 (6)	10477 (9)	5472 (5)	4345 (4)	933 (1)	2187 (2)	3687 (3)	2430 (2)	3687 (3)	1120 (1)	1120 (1)	-
Coal-Fired	P	7388 (14)	13530 (31)	8336 (19)	10529 (24)	12121 (18)	17685 (33)	9909 (18)	15729 (28)	15397 (28)	13610 (21)	9480 (17)	7612 (11)	1775 (3)	1573 (3)	-	-
	F	-	-	-	-	-	-	-	-	3500 (6)	3500 (6)	9774 (16)	12774 (21)	14774 (25)	14774 (25)	14774 (25)	14774 (25)
	T	7388 (14)	13530 (31)	8336 (19)	10529 (24)	12121 (18)	17685 (33)	9909 (18)	15729 (28)	18897 (34)	17110 (27)	19254 (33)	20386 (32)	16549 (28)	16347 (28)	14774 (25)	14774 (25)
Oil - Fired	P	1155 (9)	4338 (19)	1923 (15)	765 (14)	1666 (9)	1562 (15)	1469 (18)	752 (13)	214 (5)	190 (3)	78 (2)	-	750 (1)	-	-	200 (3)
	F	-	-	-	-	-	-	-	-	-	-	680 (1)	680 (1)	680 (1)	680 (1)	680 (1)	680 (1)
	T	1155 (9)	4338 (19)	1923 (15)	765 (14)	1666 (9)	1562 (15)	1469 (18)	752 (13)	214 (5)	190 (3)	758 (3)	680 (1)	1430 (2)	680 (1)	680 (1)	880 (4)
Gas-Fired	P	70 (1)	76 (2)	73 (2)	-	50 (1)	-	-	500 (1)	-	-	-	-	-	-	-	-
	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	T	70 (1)	76 (2)	73 (2)	-	50 (1)	-	-	500 (1)	-	-	-	-	-	-	-	-

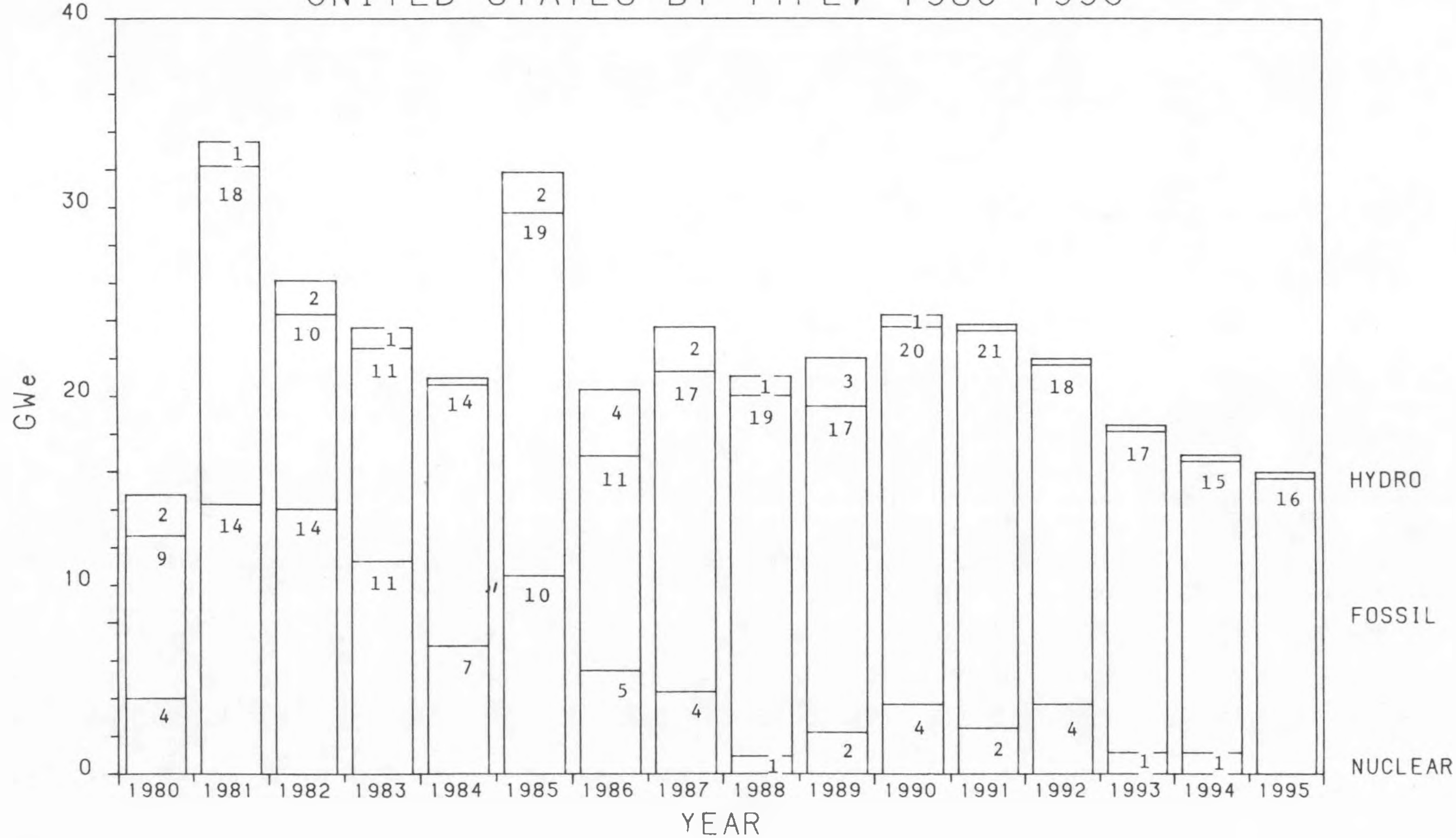
Table 1 (Continued)

Type		80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
Hydro	P	1201 (9)	863 (22)	427 (15)	1087 (18)	359 (7)	985 (11)	457 (6)	177 (6)	119 (4)	1 (1)	2 (1)	-	-	-	-	-
	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	T	1201 (9)	863 (22)	427 (15)	1087 (18)	359 (7)	985 (11)	457 (6)	177 (6)	119 (4)	1 (1)	2 (1)	-	-	-	-	-
Pump Storage	P	971 (3)	416 (7)	1367 (2)	-	-	1158 (5)	3050 (9)	2175 (4)	900 (1)	2555 (2)	300 (2)	-	-	-	-	-
	F	-	-	-	-	-	-	-	-	-	-	328 (1)	328 (1)	328 (1)	328 (1)	328 (1)	328 (1)
	T	971 (3)	416 (7)	1367 (2)	-	-	1158 (5)	3050 (9)	2175 (4)	900 (1)	2555 (2)	628 (3)	328 (1)	328 (1)	328 (1)	328 (1)	328 (1)
Total Nation	P	14776 (40)	33487 (94)	26147 (66)	23644 (67)	20957 (41)	31867 (73)	20357 (56)	23678 (56)	17563 (39)	18543 (29)	13547 (25)	10042 (13)	6212 (7)	2693 (4)	1120 (1)	2[illegible] (3)
	F	-	-	-	-	-	-	-	-	3500 (6)	3500 (6)	10782 (18)	13782 (23)	15782 (27)	15782 (27)	15782 (27)	15782 (27)
	T	14776 (40)	33487 (94)	26147 (66)	23644 (67)	20957 (41)	31867 (73)	20357 (56)	23678 (56)	21063 (45)	22043 (35)	24329 (43)	23824 (36)	21994 (34)	18475 (31)	16902 (28)	15982 (30)

Note: a Both planned and forcasted projects are included. Planned projects were obtained from U. S. DOE/EIA's Inventory of Powerplants in the United States(1981) and the U. S. NRC's Nuclear Powerplants Construction Status Report (April 1981). Forecasted projects are based on U. S. DOE/EIA's 1981 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13. This analysis does not include the experimental Clinch River Breeder Reactor (CRBR), a 350 MWe unit scheduled for construction in Oak Ridge, TN during 1982-1989. Comprehensive labor requirements for CRBR are available from: Occupational Impact of CRBR, Department of Labor Report NRC-03-79-125, March 1982.

FIGURE 1

ELECTRIC GENERATING CAPACITY ADDITIONS IN THE UNITED STATES BY TYPE, 1980-1995



facilities and "forecasted" facilities. Totals for planned additions include publicly announced plans, for most of which there are announced completion dates. Through 1987, the planned figures are also the total figures, since all the facilities that will go into commercial operation by 1987 are already planned. Beginning with 1988,the "forecasted" facilities (pseudo projects) enter the totals. These projects are generated to produce total capacity that fits the projections of total electric consumption forecasted by the Department of Energy, which in turn rest upon assumptions about the rate of American economic growth and the course of world oil prices. For 1988, the forecasted capacity additions, consisting entirely of coal-fired plants, make up 17 percent of the total new capacity. By 1990 this figure increases to 44 percent, but note that lead times for powerplant construction are so long that even by 1990 more than half of the capacity additions will consist of projects already planned and publicly announced by 1981.

In the case of nuclear plants, there are no forecasted projects, as the model assumes that all future starts are already planned. There are no currently outstanding orders for nuclear steam supply systems for installation in the United States. Even so, the currently planned nuclear projects are expected to produce capacity additions up to 1998, and to account for 7 percent of total capacity additions during 1994.

Substantial variations in the totals from year to year are perhaps more striking than long-term trends, though there are declines from 1982-1984, increases from 1988-1990, and declines from 1991-1995. The 1981 total is the high for the whole period, with the low point coming in 1995. The totals for 1980 and 1981 are not strictly comparable with later years and may be unnaturally low because they reflect actual completions, while all of the other years include projects that may be delayed or cancelled.

Nuclear power declines in importance both absolutely and relatively during the period because of the assumption concerning new starts. Its relative importance peaks at 54 percent of the total during 1982, and reaches zero in 1995. Over all years, nuclear plants account for 24 percent of capacity additions. The nuclear decline is principally offset by an increase in coal-fired plants, which increase both relatively and absolutely during most years of the forecasted period, and make up 65 percent of the new capacity expected to be installed over the 16-year span represented in the projections.

Oil-fired units tend to decline a little in importance during the years shown in Table 1 and Figure 1, and pump storage units increase mildly; they make up about 5 and 4 percent of the total capacity, respectively. Neither hydro facilities (1.6 percent) not gas-fired units (.2 of 1 percent) are of major importance during the 1980-1995 period.

Over a near time horizon, future labor requirements for construction of generating plants can be approximated quite accurately by surveys, owing to the lead time between project initiation and performance of labor at the construction site. A survey of utilities, conducted by the Department of Labor in early 1979, was the principal basis for our Projections of Cost, Duration, and On-Site Manual Labor Requirements for Constructing Electric Generating Plants, 1979-1983, September 1979. Another survey in 1981 provided data used in the formation of these projections for the 1981-1990 period, but the longer time frame of the present work has made it necessary for us to forecast projects that are not yet in the planning state.

The projection of new projects, not yet specifically planned by their owners, has made it necessary for us to make some assumptions about the consumption of electricity in the United States during the decade to come. We have relied upon forecasts made by the Department of Energy, and specifically upon the Energy Information Administration, 1981 Annual Report to Congress. These forecasts in turn rely upon a number of assumptions concerning world economies. From a variety of possible scenarios outlined in the forecasts, we have chosen the middle estimates as the basis of our projections. Most importantly, these are that the world oil price in 1980 dollars per barrel, will go from $33.89 in 1980 to $33 in 1985 before increasing to $49 in 1990, and that real American gross national product will increase at an average rate of 2.7 percent per year from 1980 to 1995. The Department of Energy's forecast, based on these and other assumptions, calls for annual growth rates for the consumption of electricity of 2.71 percent per year from 1979 to 1995.

For the early years of the projected decade, the estimates have a relatively firm basis in projects planned or already under construction. By 1990 most of these projects will be finished, and on-site labor requirements will be based more and more on future projects not yet specifically planned, and necessary to meet the 2.71 percent growth rate and replace retired generating units.

The construction schedules for electric generating units planned for commercial operation during the 1980-1995 period were obtained from the April 1981 issue of the Nuclear Regulatory Commission's "Yellow Book" (for nuclear units) and the Department of Energy's 1981 Generating Unit Reference File (for fossil and hydro units). The Yellow Book contains construction start and completion dates for the nuclear units, but the Generating Unit Reference File contains only scheduled commercial operation dates. In the latter case, construction start dates were obtained from secondary sources (such as Electrical World and Engineering News Record) or estimated from duration averages of similar units in the same time frame.

Hard information about specific known projects deteriorates in terms of total construction activity, since existing projects are completed and replaced with soft (presently unknown) projects. An illustration of the extent of this deterioration can be found in Appendix C, based on the survey of current and planned powerplant construction projects published in Electrical World for January 1981. Capacity additions not yet specifically planned must be forecasted for the latter part of this decade and the early part of the next decade if CLDS is to estimate a comprehensive labor requirement scenario for powerplants under construction during the 1980-1990 period. This is accomplished by using the Department of Energy's Midterm Energy Forecasting System (MEFS) to forecast generation capacity (by fuel type and State) through 1995. Known projects are subtracted from the forecasts and the remainder is decomposed into psuedo-projects. The planned (known) projects account for all labor requirements through 1985 but after 1985 the labor requirements are based upon a mix of planned and psuedo projects.

The cost per KWe and workhour per KWe statistics were econometrically estimated from data obtained from a CLDS survey (OMB 1215-0086) of recently completed generating units. Utilities with generating units achieving commercial operation during the 1974-1978 period were sent questionnaires in 1979 and those with units achieving operation in 1979-1981 were sent questionnaires in 1981. The questionnaires obtained data on capital costs, on-site manual workhours required for construction, county and state location, construction start and end dates, and megawatt capacity. These data were used to generate capital cost in constant 1980 dollars and on-site manual workhours per KWe of installed capacity based upon year of construction start, size, fuel type, and geographic location.

The total workhour estimates for each unit were applied to nominal facility profiles to allocate the total hours to specific occupations and then phase the utilization of each occupation throughout the construction duration. Nominal facility labor utilization profiles were developed jointly by the Contractors Mutual Association and CLDS for boiling water reactors, pressurized water reactors, coal, gas, oil, hydro, and pump storage facilities.

The estimation of the time-trend series of capital cost and on-site manual workhour requirements is treated in detail in Appendix A. Briefly, the log of total plant cost (in 1980 dollars) was regressed on the log of generating capacity, year of construction start (log of year in the nuclear plant cost equation), and a dummy variable for South (Regions IV and VI in Figure 11,) versus non-South location. Labor requirements were then estimated recursively by regressing the log of total workhours on the log of estimated total cost. The coefficient derived for megawatt capacity was used to scale the cost and labor requirements to the different plant sizes. Consequently, unit cost and workhour requirements were obtained by dividing total cost and total workhours by plant capacity.

III. Unit Capital Costs and Labor Requirements for Nominal Facilities

Tables 2 and 3 show constant dollar cost per KWe and on-site manual workhour requirements per KWe, respectively,

Table 2

Forecasts of Unit Capital Costs, ($/KWe in 1980 Dollars)

for Coal-Fired Powerplants without Scrubber

	Year of Construction Start	Non-South		South	
		300 MWE	600 MWe	300 MWe	600 MWe
Econometric Estimation	1972	516[a]	489[a]	438[a]	415[a]
	1973	544	515	461	437
	1974	573	543	485	460
	1975	603	572	511	485
	1976	635	602	538	511
	1977	669	634	567	538
	1978	705	668	597	566
	1979	742	704	629	597
	1980	782	741	663	628
Geometric Estimation	1981	819[b]	776[b]	695[b]	658[b]
	1982	854	809	724	686
	1983	886	840	751	712
	1984	914	866	775	734
	1985	939	889	796	754
	1986	959	908	813	770
	1987	974	923	826	782
	1988	984	933	834	790
	1989	990	938	839	795
	1990	990	938	839	795

Note:

a. Forecasted from the estimated regression equation shown in Table A6.

b. Rate of increase monotonically decreases from 5.3 percent cost increase from 1979-1980 to zero increase from 1989-1990.

Table 3

Forecasts of Unit Construction Workhour Requirements (WH/KWe)[a] for Coal-Fired Powerplants Without Scrubber

	Year of Construction Start	Non-South		South	
		300 MWe	600 MWe	300 MWe	600 MWe
Econometric Estimation	1972	6.3	5.6	5.5	4.8
	1973	6.6	5.9	5.7	5.1
	1974	7.0	6.1	6.0	5.3
	1975	7.3	6.4	6.3	5.6
	1976	7.6	6.7	6.6	5.8
	1977	8.0	7.1	6.9	6.1
	1978	8.4	7.4	7.2	6.4
	1979	8.8	7.7	7.6	6.7
	1980	9.2	8.1	7.9	7.0
Geometric Estimation	1981	9.6	8.4	8.3	7.3
	1982	9.9	8.8	8.6	7.6
	1983	10.2	9.1	8.8	7.8
	1984	10.5	9.4	9.1	8.0
	1985	10.8	9.5	9.3	8.2
	1986	11.0	9.7	9.5	8.4
	1987	11.2	9.8	9.6	8.5
	1988	11.3	9.9	9.7	8.6
	1989	11.3	10.0	9.8	8.6
	1990	11.3	10.0	9.8	8.6

Note:

a. Forecasted from the estimated regression equation shown in Table A5 with use of the forecasted unit capital costs shown in Table 2.

for coal-fired plants with construction starts from 1972 to 1990. These tables reflect the assumption that after 1980 (the last year for which we have actual cost experience data) requirements will increase at a decreasing rate before stabilizing in 1990. It should be noted that the 1972-1980 estimates were econometrically derived from "hard" data, while the 1980-1990 estimates are geometric projections based upon the assumption that "things will get better" but only slowly.

The preceding assumption reflects an underlying "social Newtonianism" law which holds that a social phenomenon in progress will remain in progress until acted upon by an external force(s). In the instant case external forces may be conceived as federal and state efforts to reduce impacts of environmental and safety regulation and licensing processes on utility investment costs and such iniatives as the Business Roundtable's Construction Industry Cost Effectiveness Project.

Thus the current Zeitgeist appears, at least to us, to hold in high favor attempts by labor, management and government to increase productivity and output. This then becomes an explicit assumption to our forecasts of real cost and labor requirements to construct future electric generating capacity replacements and additions.[4]

An increase in both constant (1980) dollar costs and workhour labor requirements over time is the most striking characteristic of Tables 2 and 3. From 1972 to 1980, dollar costs increased about 52 percent, and workhours increased about 45 percent per KWe of installed capacity over the 8-year span. Costs were about 18 percent higher in constant dollars and 16 percent higher in workhours in the non-South by comparison with the South. The larger projects benefitted from economies of scale, with 12 percent fewer workhours and 5 percent lower capital costs for 600 MWe plants as compared to 300 MWe plants. Scrubbers (FGD) increase cost approximately 20 percent and workhours about 18 percent.[5] (It is assumed that future coal and oil plants will have scrubbers.) The 1980-1990 cost and labor estimates are based only upon the "Newtonian" law and were assumed to increase by 21 percent and 18 percent respectively over the 1980-1990 span.

There are a number of reasons for the increased costs, and a thorough explanation would rapidly take us beyond the scope of the present study. It should be emphasized that they cannot be explained by general inflation, and it can be speculated that increasingly stringent government regulations were probably an important part of the historical cost increases. Some other possibilities worth consideration would include resort to more difficult and expensive sites as the best ones are used first, declining productivity of labor resulting either from changes in the characteristics of the work force or the characteristics of the jobs performed, personnel shortages in management, engineering, and the trades and deterioration of the organization of work at the increasingly large job-sites. The regional cost difference has been established statistically, but a complete explanation will not be attempted here. The most obvious difference, milder southern weather that allows relatively inexpensive year-round outdoor work, is probably a large part of the cause, but such factors as differences in labor productivity arising from customary workrules or a higher degree of urbanization in the non-South region might also play a part. It seems unlikely that lower wage rates in the South explain the lower costs in that region, for if this were the case one would expect southern builders to substitute labor for capital, leading to a larger (not smaller) expenditure of labor hours in this region.

Nuclear plants are analyzed in the same way in Tables 4 and 5. Here the increases over time are even more impressive, with constant dollar costs increasing by about 200 percent, and on-site manual workhour requirements increasing by about 128 percent during the 11 years from 1967 to 1978 (the last year in which cost estimates are available). The cost advantage to the South was about the same as for coal-fired plants, with the non-South about 15 percent higher in constant dollars and 11 percent higher in workhours. It is again true that general inflation cannot be an explanation for the cost increases, and it seems likely that increasingly stringent government regulations, including both safety and environmental requirements, play an important role in the increased dollar and workhour requirements for these construction projects.[6] The data again show significant economies of scale in lower dollar costs and workhour requirements per MWe of capacity for the larger plants.

Table 4

Forecasts of Unit Capital Costs ($/KWe in 1980 Dollars)

for Nuclear Powerplants

	Year of Construction Start	Non-South		South	
		900 MWe	1200 MWe	900 MWe	1200 MWe
Econometric Estimation	1967	622[a]	559[a]	541[a]	486[a]
	1968	789	709	685	616
	1969	934	839	811	729
	1970	1065	957	925	831
	1971	1185	1065	1029	925
	1972	1297	1165	1126	1012
	1973	1403	1260	1218	1094
	1974	1503	1350	1305	1173
	1975	1599	1436	1388	1247
	1976	1690	1519	1468	1319
	1977	1779	1598	1545	1388
	1978	1864	1675	1619	1454
Geometric Estimation	1979	1946[b]	1749[b]	1690[b]	1518[b]
	1980	2024	1819	1758	1579
	1981	2097	1884	1821	1635
	1982	2164	1944	1879	1688
	1983	2224	1999	1932	1735
	1984	2278	2047	1978	1777
	1985	2323	2088	2018	1812
	1986	2360	2121	2050	1841
	1987	2389	2147	2075	1863
	1988	2408	2164	2091	1878
	1989	2417	2172	2100	1886
	1990	2417	2172	2100	1886

Note:

a. Forecasted from the estimated regression equation shown in Table A6.

b. Rate of increase monotonically decreases from 4.8 percent cost increase from 1977-1978 to zero increase from 1989-1990.

Table 5

Forecasts of Unit Construction Work-Hour Requirements (WH/KWe)[a] for Nuclear Powerplants

	Year of Construction Start	Non-South		South	
		900 MWe	1200 MWe	900 MWe	1200 MWe
Econometric Estimation	1967	10.2	8.7	9.1	7.9
	1968	12.2	10.5	10.9	9.4
	1969	13.8	11.9	12.4	10.7
	1970	15.3	13.1	13.7	11.8
	1971	16.6	14.2	14.9	12.8
	1972	17.7	15.2	15.9	13.7
	1973	18.8	16.2	16.9	14.5
	1974	19.8	17.0	17.8	15.3
	1975	20.8	17.8	18.7	16.0
	1976	21.7	18.6	19.5	16.7
	1977	22.5	19.3	20.2	17.4
	1978	23.3	20.0	21.0	18.0
Geometric Estimation	1979	24.1	20.7	21.6	18.6
	1980	24.8	21.3	22.3	19.2
	1981	25.5	21.9	22.9	19.7
	1982	26.1	22.4	23.4	20.2
	1983	26.6	22.9	23.9	20.6
	1984	27.1	23.3	24.4	20.9
	1985	27.5	23.7	24.7	21.3
	1986	27.8	23.9	25.0	21.5
	1987	28.1	24.2	25.3	21.7
	1988	28.3	24.3	25.4	21.8
	1989	28.4	24.4	25.5	21.9
	1990	28.4	24.4	25.5	21.9

Note:

a Forecasted from the estimated regression equation shown in Table A5 on the basis of the forecasted unit capital costs shown in Table 4.

A comparison of the estimates for nuclear plants in Table 4 and coal-fired plants in Table 2 shows a substantial advantage in capital cost for coal-fired plants, with costs for comparable nuclear capacity more than 2 1/2 times as high as coal. (Coal-fired plant costs do not include the cost of scrubbers which in all liklihood will be required for future plants.) Of course these advantages in construction costs may or may not be large enough to offset the higher fuel costs of the coal-fired plants, or to compensate for future changes in the coal/uranium price ratio. Differences in operation and maintenance costs and reliability of coal-fired versus nuclear powerplants cloud the issue of comparative life-cycle costs even further, and the reader is cautioned against deriving overall production cost conclusions solely from capital cost estimates.[7]

Constant dollar cost figures and workhour requirements for hydro-dam and pump storage powerplants are shown in Tables 6 and 7. These are not comparable to the figures for nuclear or coal-fired facilities shown in Tables 2-5 because dams cannot be standardized in design, and costs are heavily influenced by the peculiarities of the site and the type of dam. It was not possible to isolate the influence of region or year of start, as in the nuclear and coal cases, partly because of the small number of observations --- 15 dams and 6 pump storage facilities were included in the survey. The remaining explanatory factor is capacity in MWe. It is notable that the cost figures (Table 6) show economies of scale for both pump storage and hydro projects, conforming to the pattern of nuclear and fossil plants noted earlier. By way of contrast, the workhour requirements (Table 7) show economies of scale for pump storage, but diseconomies for hydro facilities. This is perhaps explained by the fact that small dams are most often constructed of earth (with low labor intensity) while larger dams are typically made of concrete, which requires more labor inputs.

Although a few oil-fired and gas-fired plants will be under construction during the 1980-1990 period (see Table 1), there was insufficient activity during the 1977-1980 period to estimate capital cost or labor requirement time-trends for these types of plants. Therefore, results of an earlier analysis of gas and oil plants built in the late 1960's and early 1970's were used to estimate 1980 labor requirements. The estimates of 1980 requirements for gas plants are: South 300 MWe --6.8 WH/KWe; South 500 MWe --6.2

Table 6

Forecasts of Unit Capital Costs ($/KWe in 1980 Dollars)[a]
for Hydro-Dam and Pump Storage Powerplants

TYPE MWe	50	100	200	400	600	800	1000	1200	1400
Hydro-Dam	1415	1138	915	736	648	592	552	521	497
Pump-Storage	779	666	570	487	444	416	396	380	367

NOTE: a. Forecasted from the estimated regression equation shown in Table A6.

Table 7

Forecasts of Unit Construction Work-Hour Requirements (WH/KWe)[a]

for Hydro-Dam and Pump Storage Powerplants

TYPE MWe	50	100	200	400	600	800	1000	1200	1400
Hydro-Dam	14.6	16.0	17.5	19.1	20.2	21.0	21.6	22.1	22.6
Pump-Storage	25.8	15.7	10.6	8.1	7.2	6.8	6.5	6.4	6.2

NOTE: a. Forecasted from the estimated regression equation shown in Table A5.

WH/KWe; non-South 300 MWe -- 7.5 WH/KWe; non-South 500 MWe -- 6.9 WH/KWe. The estimates for 1980 oil plants are: South 500 MWe -- 6.7 WH/KWe; South 800 MWe -- 6.3 WH/KWe; non-South 500 MWe -- 7.6 WH/KWe; and non-South 800 MWe 7.2 WH/KWe. Scrubbers add about 20 percent to the workhours per KWe for oil-fired plants.

Figures 2 and 3 show plots of the cost and workhour data for coal-fired plants shown in Tables 2 and 3. Figures 4 and 5 show plots of the same data adjusted for the inclusion of scrubbers. The figures reflect the assumption that after 1980 cost and labor requirements begin to stabilize.

Figures 6, 7, and 8 show plots of the cost and workhour requirement data for nuclear plants shown in Tables 4 and 5. Again, the effect of the levelizing cost assumption can be observed, but since 1978 starts were the last for which cost and workhour requirement estimates were available (no nuclear powerplant projects have been initiated since 1978), the cost and labor requirements begin stabilizing in 1978 rather than 1980.

Figures 9 and 10 show cost and labor requirements for hydro and pump storage facilities, which are plots of the numbers in Tables 6 and 7. As discussed earlier, they do not distinguish geographic areas or starting dates, but show unit costs as a function of capacity.

IV. National and Regional Labor Requirements

Table 8 shows projected labor requirements for the nation during the 1980-1990 period. Over the whole decade, there is a modest decrease in total labor requirements associated with powerplant construction. The decrease from 321 million workhours in 1980 to 246 million workhours in 1990 is equivalent to an annual decline of 2.1 percent, compounded annually. This total conceals numerous significant changes, both from year to year and within crafts. Total employment is projected to decrease from 1980 through 1983, reaching a low point in 1983 and 1984 at 77 percent of the 1980 total. Further declines in 1985 and 1986 bring the 1986 total to the lowest of the decade, 87 percent of the 1983-1984 figure, or only 67 percent of the 1980 workhour

FIGURE 2

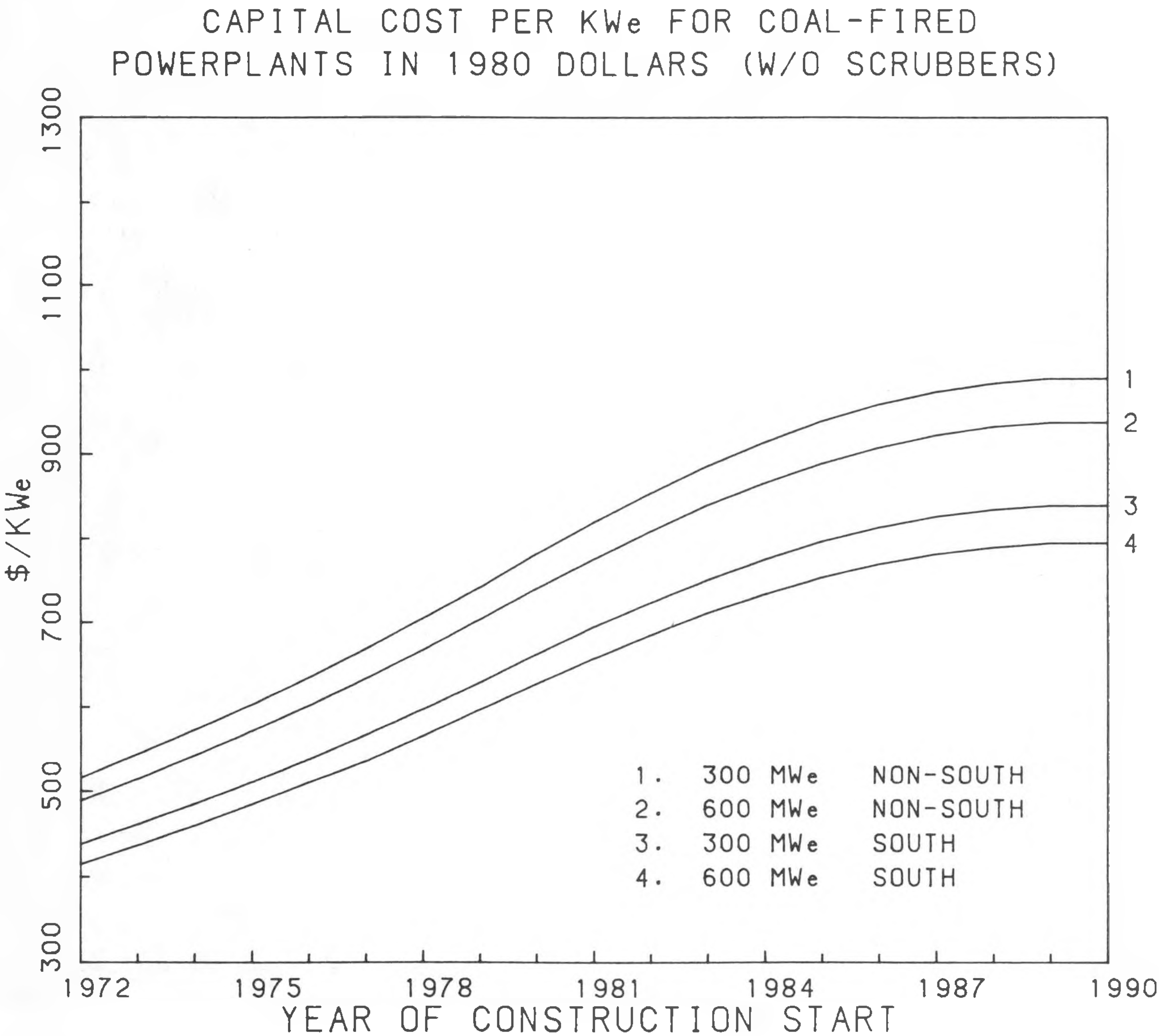

CAPITAL COST PER KWe FOR COAL-FIRED
POWERPLANTS IN 1980 DOLLARS (W/O SCRUBBERS)
$/KWe
300
500
700
900
1100
1300
1972
1975
1978
1981
1984
1987
1990
YEAR OF CONSTRUCTION START
1
2
3
4
1. 300 MWe NON-SOUTH
2. 600 MWe NON-SOUTH
3. 300 MWe SOUTH
4. 600 MWe SOUTH

FIGURE 3

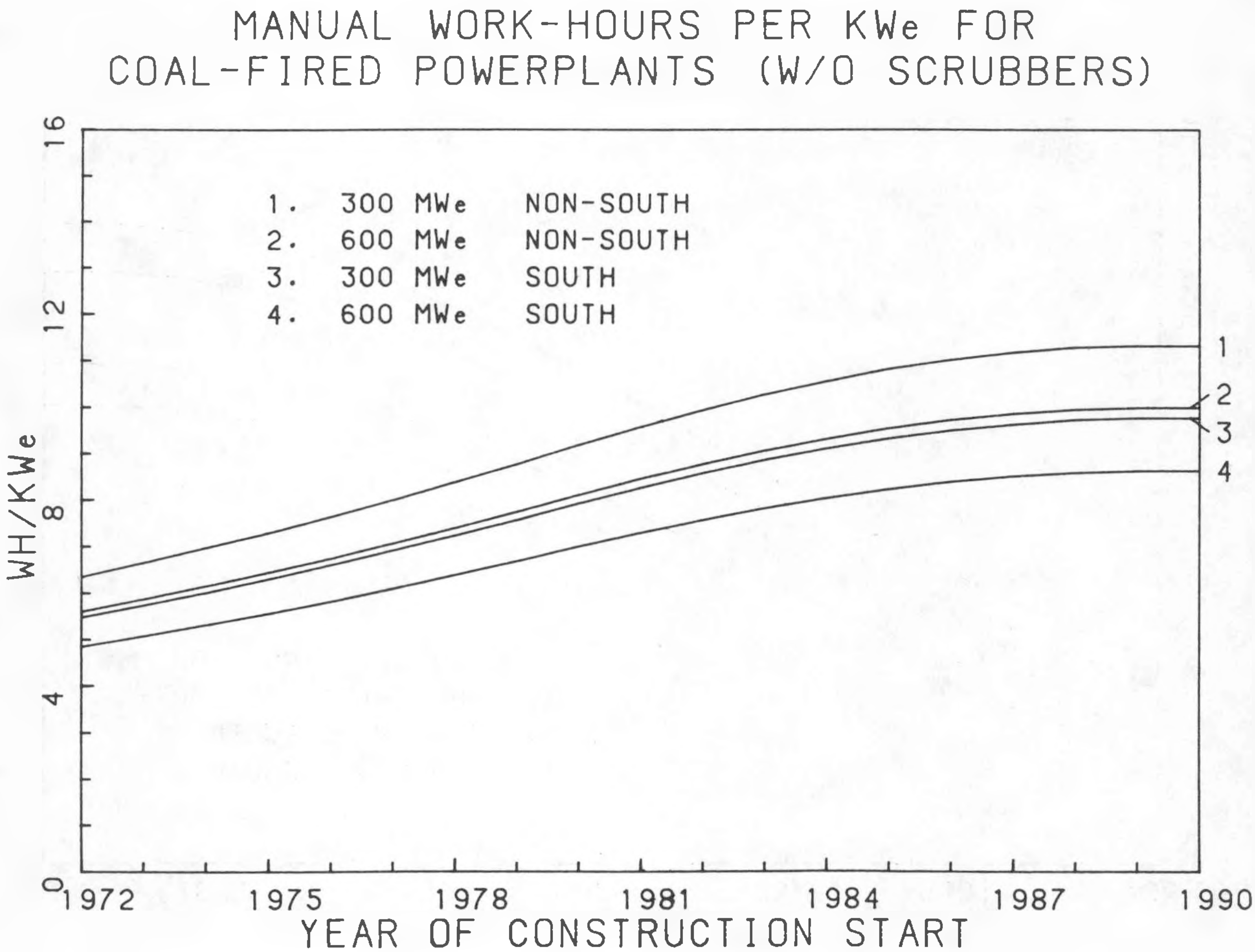

MANUAL WORK-HOURS PER KWe FOR
COAL-FIRED POWERPLANTS (W/O SCRUBBERS)
1. 300 MWe NON-SOUTH
2. 600 MWe NON-SOUTH
3. 300 MWe SOUTH
4. 600 MWe SOUTH
WH/KWe
0
4
8
12
16
1972
1975
1978
1981
1984
1987
1990
YEAR OF CONSTRUCTION START
1
2
3
4

FIGURE 4

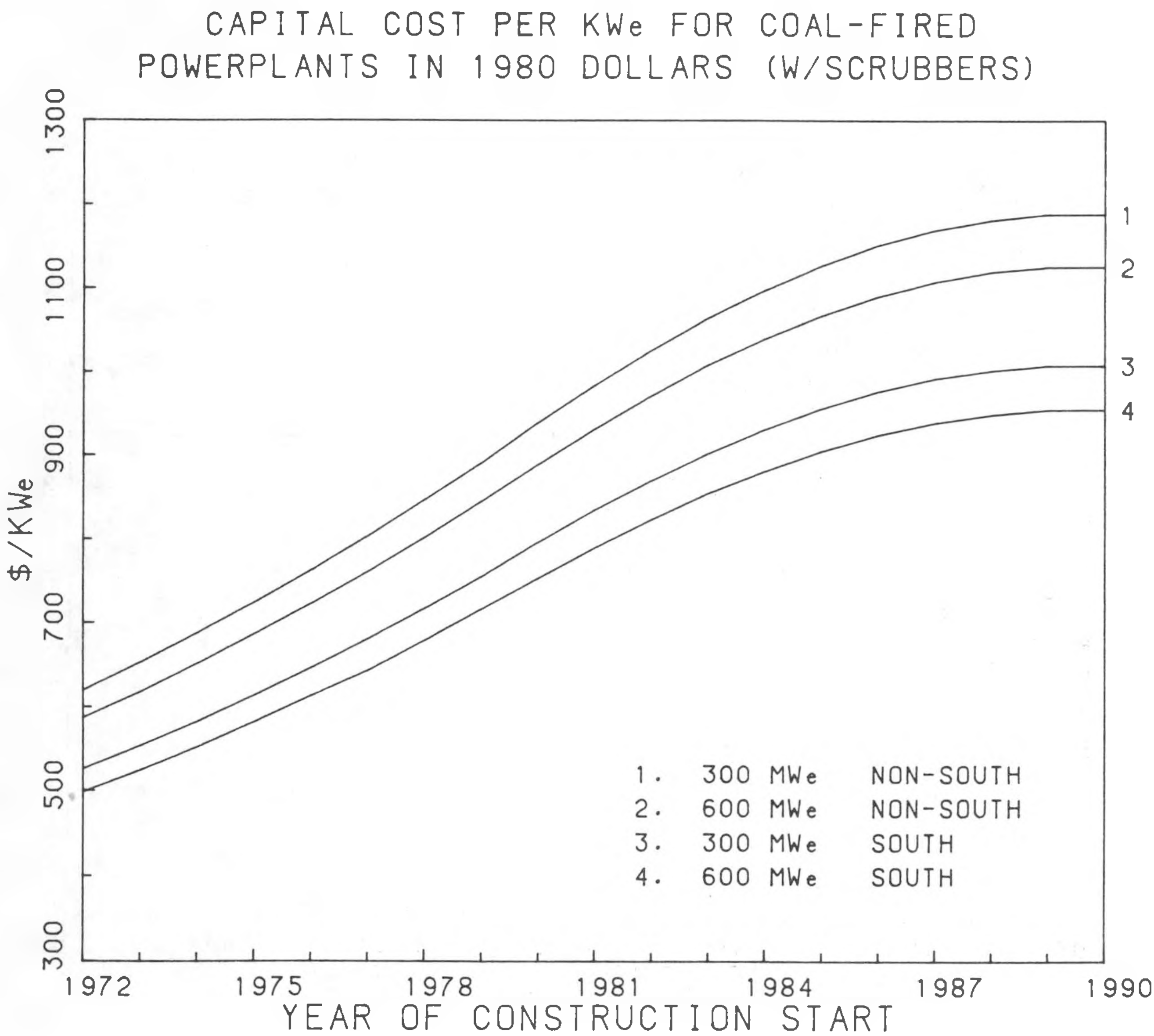

CAPITAL COST PER KWe FOR COAL-FIRED
POWERPLANTS IN 1980 DOLLARS (W/SCRUBBERS)
$/KWe
300
500
700
900
1100
1300
1972
1975
1978
1981
1984
1987
1990
YEAR OF CONSTRUCTION START
1
2
3
4
1. 300 MWe NON-SOUTH
2. 600 MWe NON-SOUTH
3. 300 MWe SOUTH
4. 600 MWe SOUTH

FIGURE 5

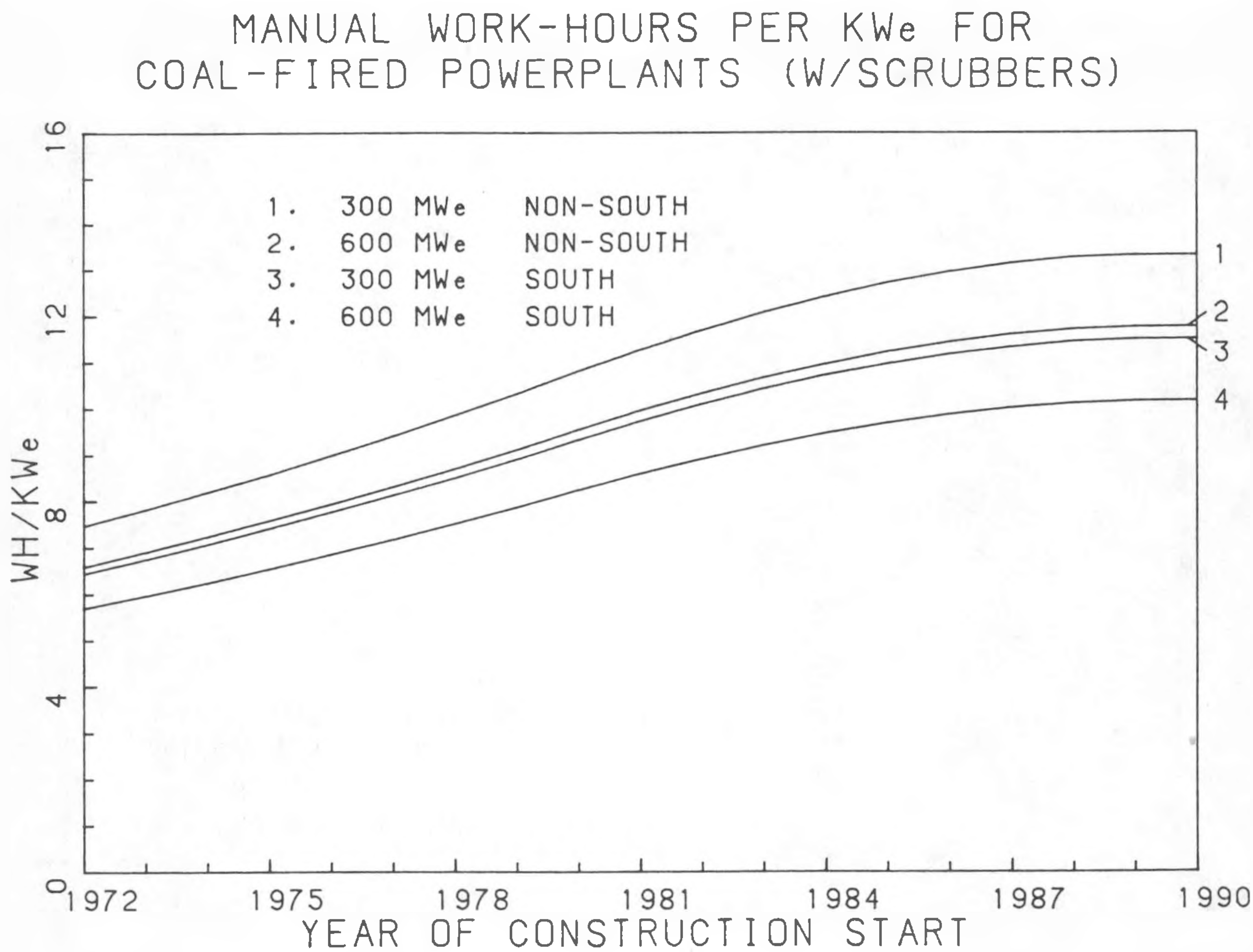

MANUAL WORK-HOURS PER KWe FOR
COAL-FIRED POWERPLANTS (W/SCRUBBERS)
1. 300 MWe NON-SOUTH
2. 600 MWe NON-SOUTH
3. 300 MWe SOUTH
4. 600 MWe SOUTH
WH/KWe
0
4
8
12
16
1972
1975
1978
1981
1984
1987
1990
YEAR OF CONSTRUCTION START
1
2
3
4

FIGURE 6

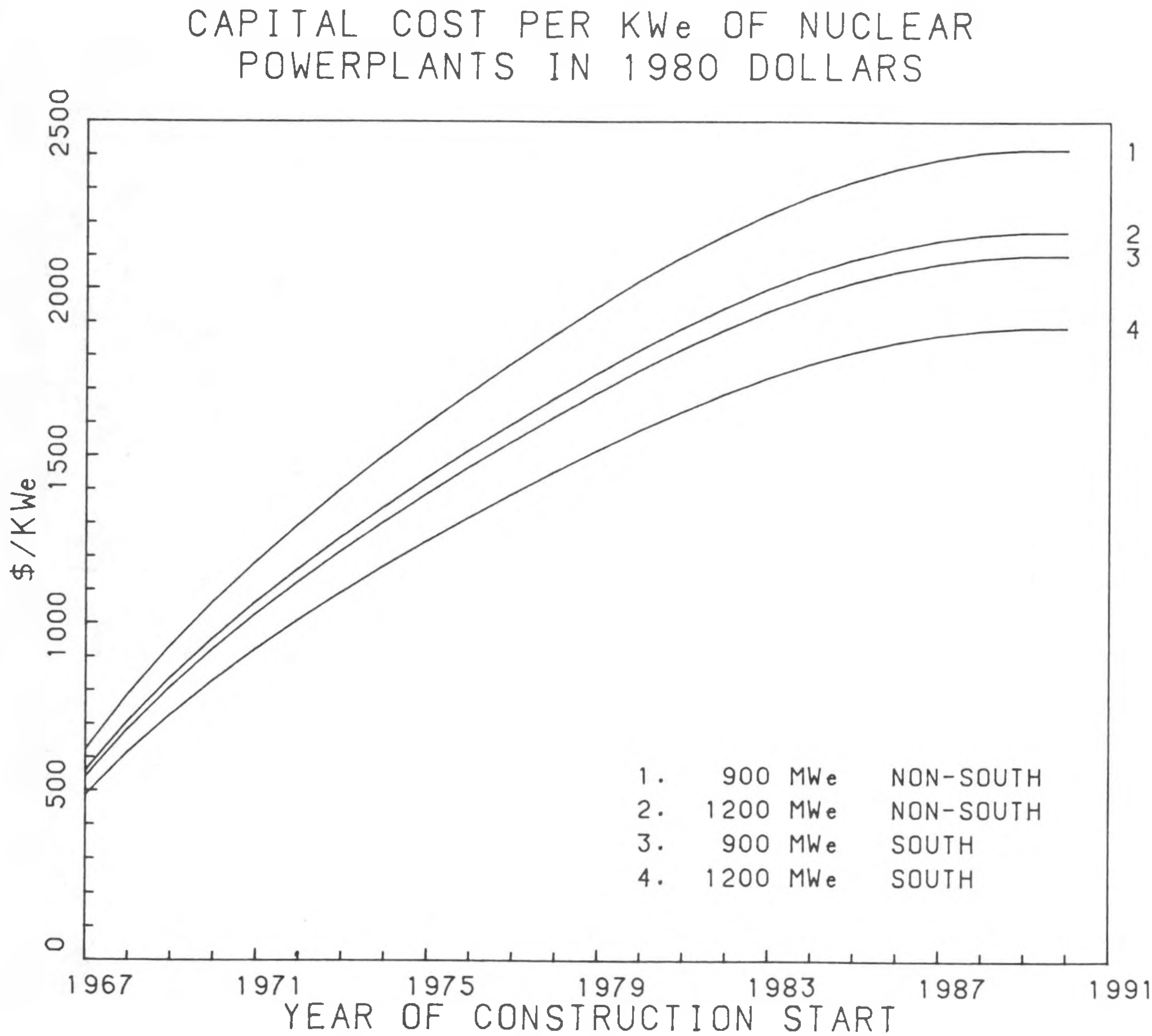

CAPITAL COST PER KWe OF NUCLEAR
POWERPLANTS IN 1980 DOLLARS
$/KWe
0
500
1000
1500
2000
2500
1967
1971
1975
1979
1983
1987
1991
YEAR OF CONSTRUCTION START
1
2
3
4
1. 900 MWe NON-SOUTH
2. 1200 MWe NON-SOUTH
3. 900 MWe SOUTH
4. 1200 MWe SOUTH

FIGURE 7

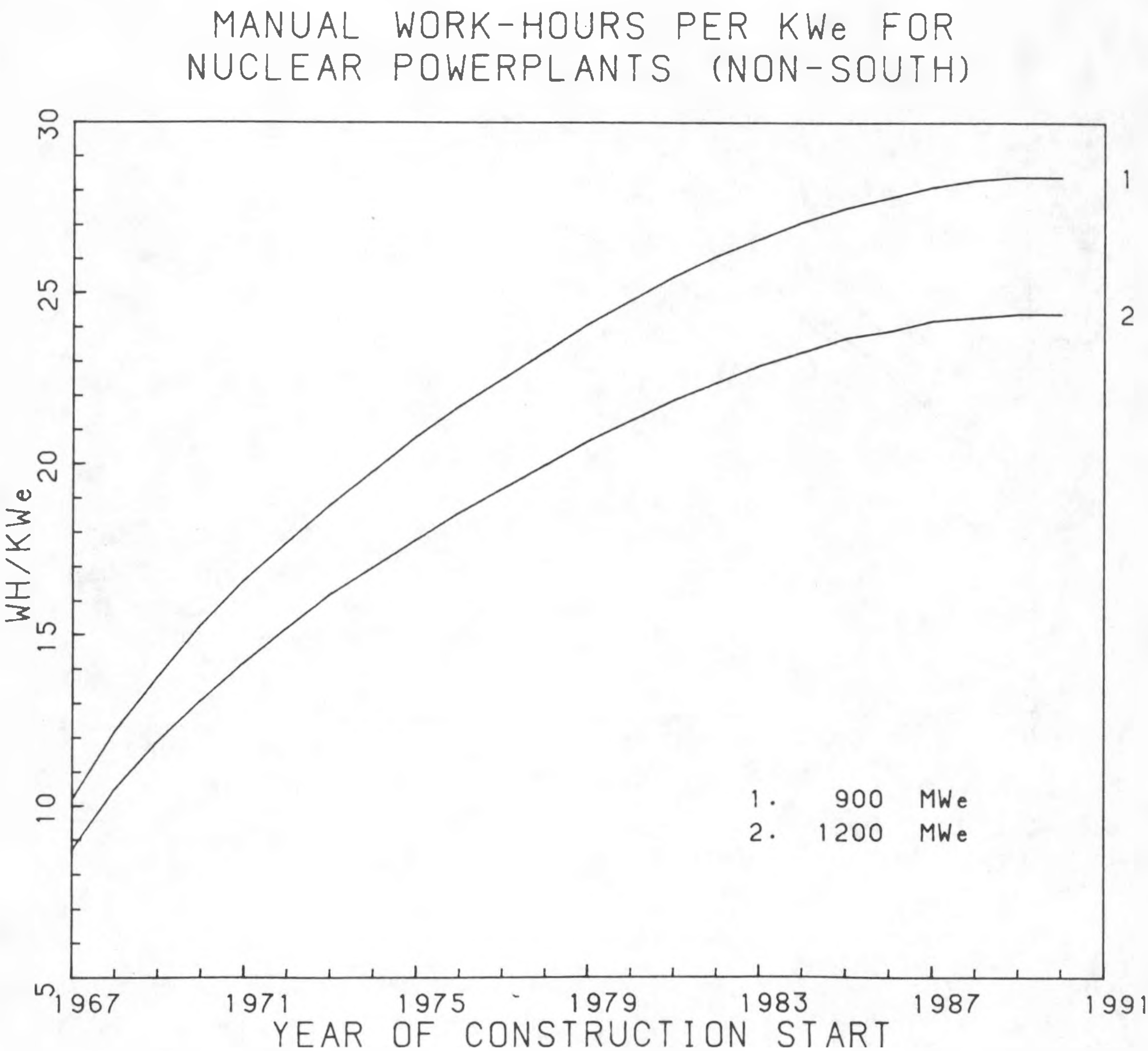

MANUAL WORK-HOURS PER KWe FOR
NUCLEAR POWERPLANTS (NON-SOUTH)
WH/KWe
5
10
15
20
25
30
1967
1971
1975
1979
1983
1987
1991
YEAR OF CONSTRUCTION START
1
2
1. 900 MWe
2. 1200 MWe

FIGURE 8

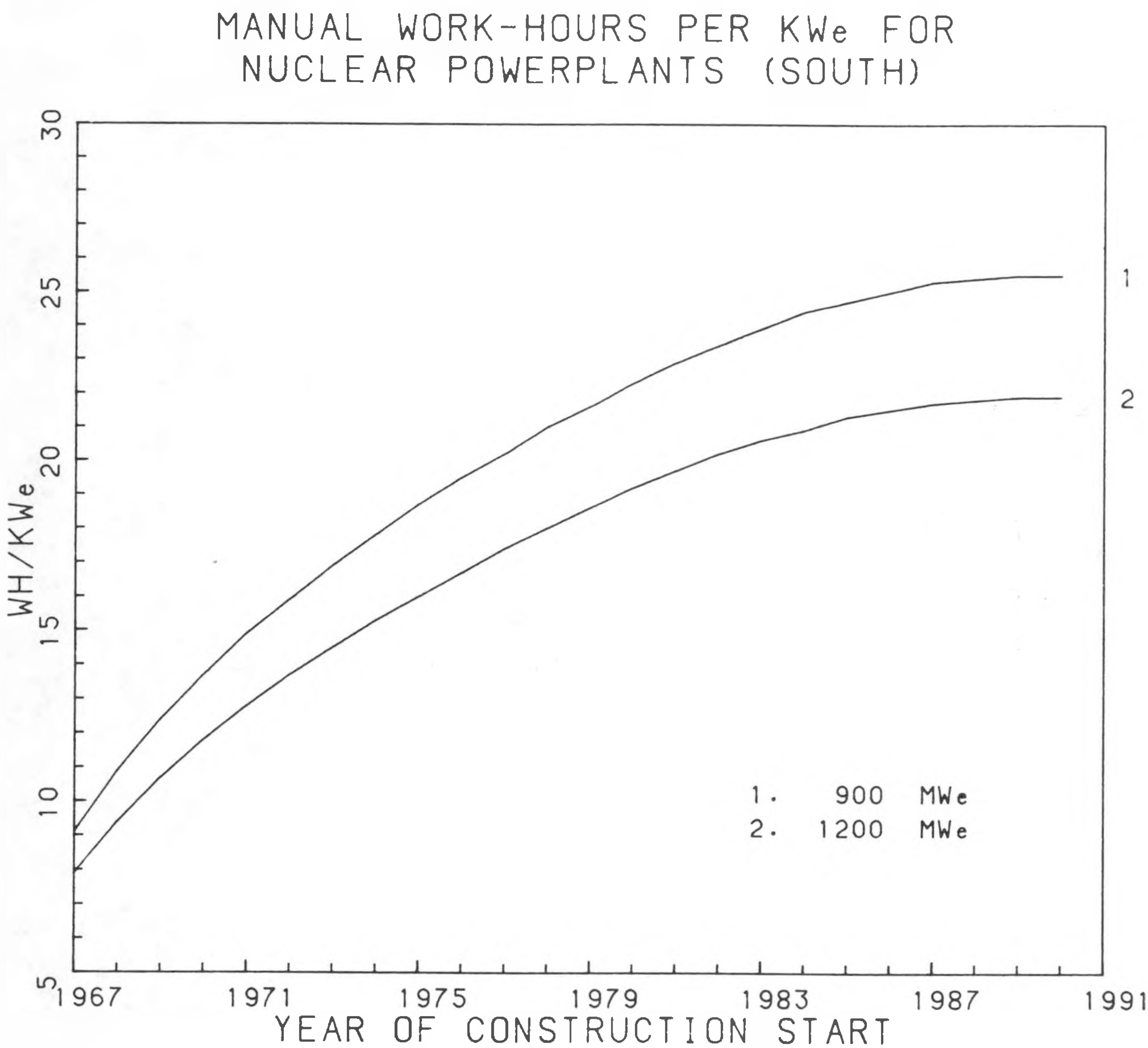

MANUAL WORK-HOURS PER KWe FOR
NUCLEAR POWERPLANTS (SOUTH)
WH/KWe
30
25
20
15
10
5
1967
1971
1975
1979
1983
1987
1991
YEAR OF CONSTRUCTION START
1
2
1. 900 MWe
2. 1200 MWe

FIGURE 9

CONSTRUCTION COST PER KWe FOR HYDRO AND PUMPED STORAGE POWERPLANTS IN 1975 DOLLARS

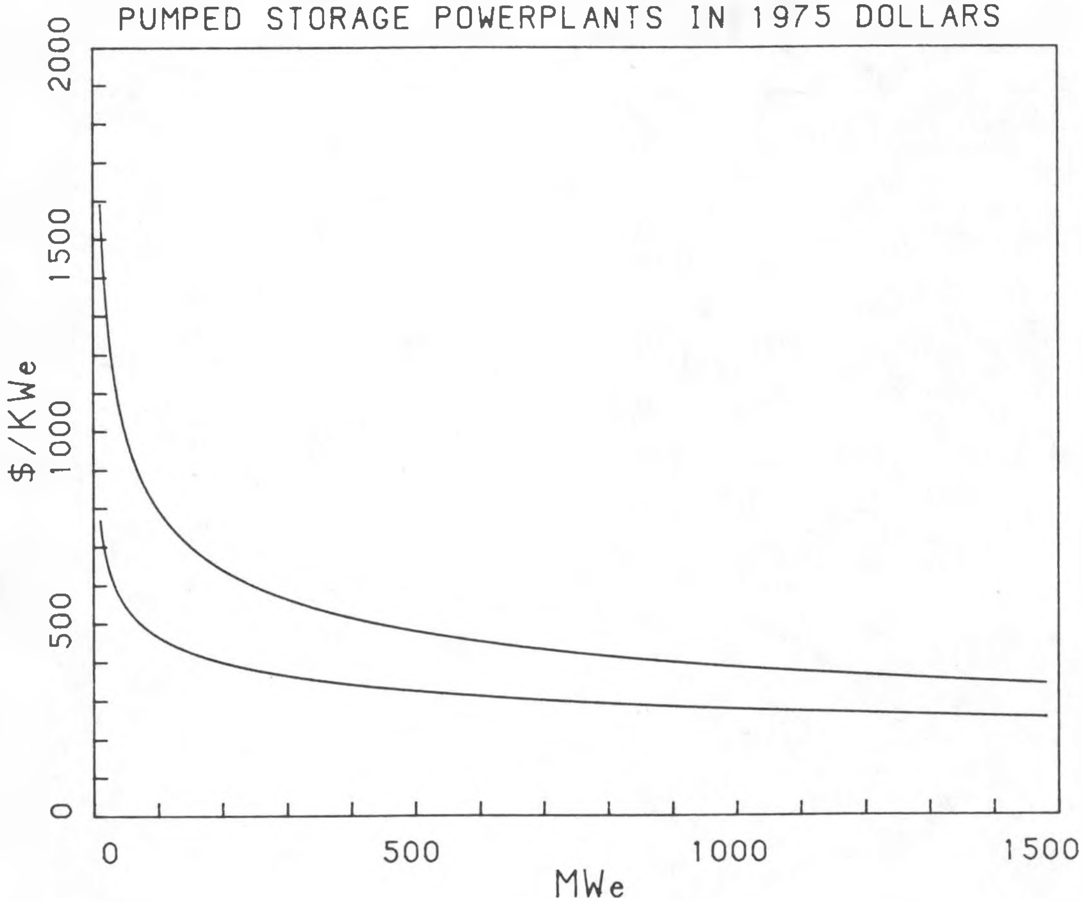


FIGURE 10

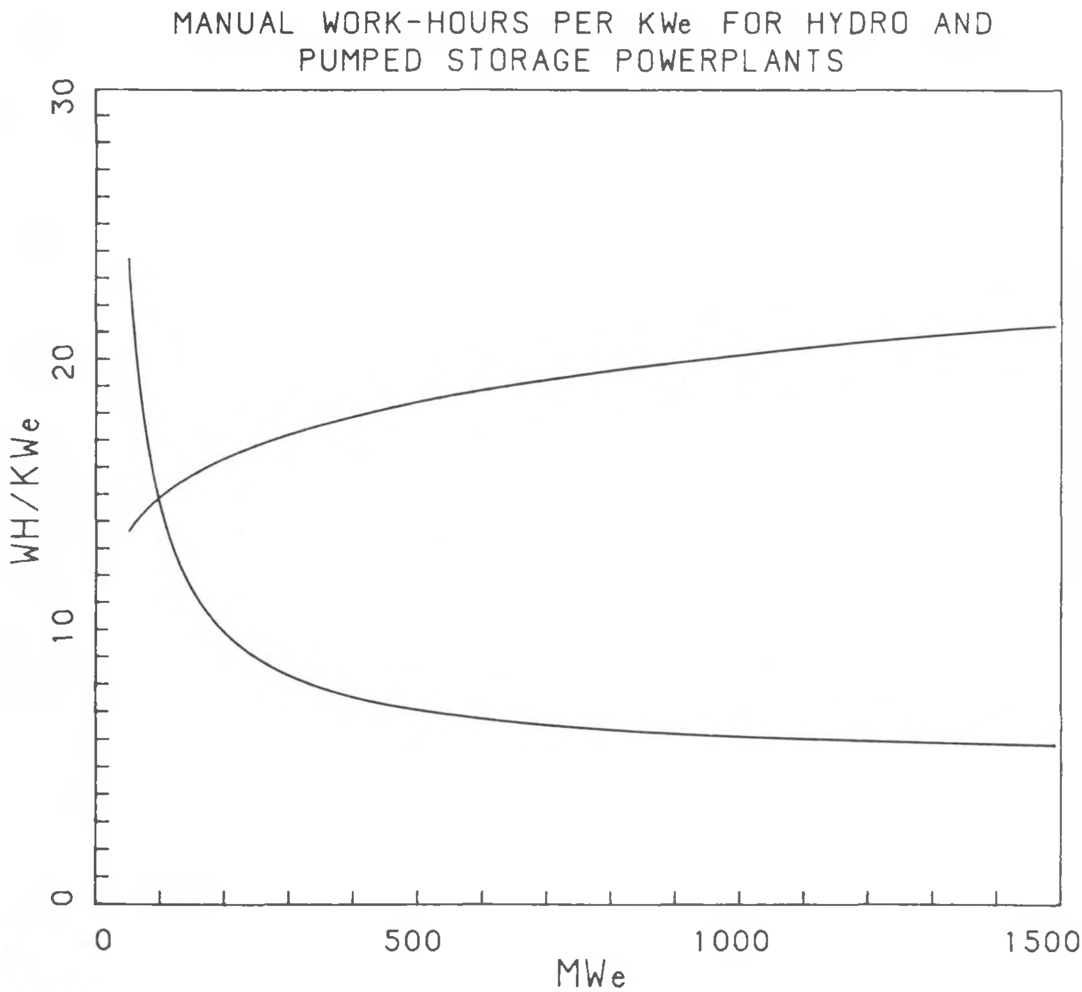

MANUAL WORK-HOURS PER KWe FOR HYDRO AND
PUMPED STORAGE POWERPLANTS
30
20
10
0
WH/KWe
0
500
1000
1500
MWe

TABLE 8

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=NATIONAL TOTAL

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	6476	7009	6581	6620	7091	6199	5677	5751	7254	8567	7221	74447
BOILERMAKERS	24191	21615	21665	25397	25963	24212	24894	30143	35342	35416	32595	301434
BRICKLAYERS	1154	894	902	862	852	877	896	1076	1026	973	943	10456
CARPENTERS	32544	28163	24323	23621	24158	22601	22352	24357	25345	24562	22538	274564
CEMENT MASONS	4120	3703	3245	3024	3136	3034	3027	3233	3405	3246	2997	36169
ELECTRICIANS	47742	46019	38710	34794	34352	31020	29649	34443	38496	41219	36255	412700
IRON WORKERS	25921	22622	20550	20161	20415	18762	18726	21425	22313	21650	20266	232811
LABORERS	46482	43206	37233	36079	36445	31748	30540	32388	34522	34219	31634	394495
MILLWRIGHTS	8736	8398	7365	7131	7573	7228	6342	6850	7737	8051	7199	82611
OPERATING ENGINEERS	24379	22483	20511	20292	20242	18055	18222	19184	20526	19652	18082	221627
PAINTERS	6593	6585	5753	4810	4800	4309	3737	3848	4171	4450	3995	53052
PIPEFITTERS	73830	69917	56596	49687	47942	42465	39763	46123	51136	54742	48876	581079
SHEETMETAL WORKERS	5186	5535	4346	4193	4258	4003	3403	4005	4661	5179	4339	49109
TRUCK DRIVERS	12242	10920	9616	9240	9001	8200	8283	8594	9106	8633	7753	101588
OTHERS	1772	1428	1450	1639	1770	1676	1378	1233	1258	1190	1067	15862
TOTAL	321370	298500	258849	247552	247998	224388	216888	242652	266298	271750	245760	2842004

TABLE 8 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=NATIONAL TOTAL

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	1.6	7.8	-19.9	27.8	-0.5	32.3	1989
BOILERMAKERS	-10.4	19.8	-4.1	42.0	-7.8	46.4	1989
BRICKLAYERS	-21.8	-5.6	5.2	14.5	-8.1	0.0	1980
CARPENTERS	-25.3	-0.7	-7.5	13.4	-11.1	0.0	1980
CEMENT MASONS	-21.2	-3.4	-3.5	12.5	-12.0	0.0	1980
ELECTRICIANS	-18.9	-11.3	-13.7	29.8	-5.8	0.0	1980
IRON WORKERS	-20.7	-0.7	-8.3	19.2	-9.2	0.0	1980
LABORERS	-19.9	-2.1	-16.2	13.0	-8.4	0.0	1980
MILLWRIGHTS	-15.7	2.8	-16.3	22.0	-6.9	0.0	1980
OPERATING ENGINEERS	-15.9	-1.3	-10.0	12.6	-11.9	0.0	1980
PAINTERS	-12.7	-16.6	-22.2	11.6	-4.2	0.0	1980
PIPEFITTERS	-23.3	-15.3	-17.1	28.6	-4.4	0.0	1980
SHEETMETAL WORKERS	-16.2	-2.0	-20.1	37.0	-6.9	6.7	1981
TRUCK DRIVERS	-21.5	-6.4	-8.0	9.9	-14.9	0.0	1980
OTHERS	-18.2	22.0	-22.2	-8.7	-15.1	0.0	1980
TOTAL	-19.5	-4.2	-12.5	22.8	-7.7	0.0	1980

requirements. The nadir in 1986 is followed by three years of increases, pushing the 1989 total 25 percent higher than 1986, and only 15 percent lower than the 1980 figure, the highest of the decade. In the final year requirements fall another 10 percent, yielding the total decline of 24 percent for the ten-year period.

The division into two-year periods shows four biennia of decline more than offsetting the 22.8 percent increase in 1986-88. The component crafts show differing trends from the total, but peak demand is reached in 1980 for twelve of the fifteen crafts, and the low point comes in 1986 for nine of them. Over the whole period, demand increases only for boilermakers (35 percent) and asbestos workers (12 percent); the greatest declines in requirements are for painters, truck drivers, and pipefitters, of 39, 37, and 34 percent, respectively. These varied rates produce a significant change in the relative importance of the crafts. Boilermakers contribute 13.3 percent of the required work force in 1990, by comparison with 7.5 percent in 1980, while pipefitters fall from 23 percent of the labor requirements in 1980 to 19.9 percent in 1990. Table 8 shows all the craft shifts. Changes in importance of the different crafts are largely the result of a change from nuclear to coal generation during the decade.

Tables 9-18 show patterns of changes in labor requirements associated with the construction of new powerplants (including both capacity expansions and replacements) over the period for each of the ten DOL regions (Figure 11). Many of the regions diverge significantly from the national pattern. Two regions are expected to experience an increase in labor demand from powerplant construction, while the other eight are expected to show declines in demand.

In 1980, the Southeastern Region (IV) had 24.1 percent of the total national labor requirements, by far the largest of any region. In 1990, this share will decrease to 23.0 percent, and the Southwestern Region (VI) will be the most important of the regions, with 23.4 percent of the national total.

Three other regions are expected to undergo substantial losses of powerplant construction labor requirements relative to the nation. These are New England (Region I), which is projected to fall from 5.0 percent to .9 percent of the

TABLE 9

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=1 (CT-ME-MA-NH-RI-VT)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	254	283	312	233	267	125	115	161	44	87	82	1966
BOILERMAKERS	1231	836	517	754	394	393	484	290	232	240	281	5651
BRICKLAYERS	63	50	24	27	23	14	11	11	8	6	13	250
CARPENTERS	1309	890	664	453	377	332	256	173	138	146	181	4920
CEMENT MASONS	194	139	106	62	56	38	29	21	15	17	21	698
ELECTRICIANS	2953	2824	1862	1363	858	528	467	441	219	279	320	12114
IRON WORKERS	1095	715	625	426	361	433	288	198	188	173	249	4752
LABORERS	2123	1611	1256	870	706	544	591	281	177	199	233	8591
MILLWRIGHTS	394	426	302	255	193	105	107	94	46	56	63	2041
OPERATING ENGINEERS	985	693	463	363	362	360	347	180	133	146	180	4212
PAINTERS	292	294	367	225	270	102	45	44	17	26	20	1703
PIPEFITTERS	4285	4273	3014	2434	1462	605	625	493	263	331	351	18137
SHEETMETAL WORKERS	263	258	187	138	70	81	69	62	38	50	46	1261
TRUCK DRIVERS	573	413	306	282	188	126	160	92	39	51	56	2285
OTHERS	64	46	37	29	18	13	10	8	5	6	7	242
TOTAL	16079	13751	10040	7913	5605	3800	3605	2549	1563	1814	2104	68821

TABLE 9 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=1 (CT-ME-MA-NH-RI-VT)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	22.8	-14.4	-57.0	-61.9	88.0	22.8	1982
BOILERMAKERS	-58.0	-23.8	23.0	-52.1	21.2	0.0	1980
BRICKLAYERS	-62.2	-3.8	-52.4	-24.9	52.5	0.0	1980
CARPENTERS	-49.3	-43.2	-32.0	-46.3	31.3	0.0	1980
CEMENT MASONS	-45.3	-47.6	-46.9	-49.3	40.6	0.0	1980
ELECTRICIANS	-36.9	-53.9	-45.6	-53.0	45.9	0.0	1980
IRON WORKERS	-43.0	-42.1	-20.4	-34.6	32.2	0.0	1980
LABORERS	-40.8	-43.8	-16.2	-70.1	31.8	0.0	1980
MILLWRIGHTS	-23.3	-36.1	-44.4	-56.9	37.5	8.2	1981
OPERATING ENGINEERS	-53.0	-21.9	-4.0	-61.6	34.8	0.0	1980
PAINTERS	25.6	-26.4	-83.4	-61.0	16.7	25.6	1982
PIPEFITTERS	-29.7	-51.5	-57.3	-57.9	33.3	0.0	1980
SHEETMETAL WORKERS	-29.0	-62.4	-1.8	-45.4	23.0	0.0	1980
TRUCK DRIVERS	-46.6	-38.5	-15.2	-75.7	43.3	0.0	1980
OTHERS	-43.2	-51.6	-43.5	-49.3	41.0	0.0	1980
TOTAL	-37.6	-44.2	-35.7	-56.6	34.6	0.0	1980

TABLE 10

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=2 (NJ-NY)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)										
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	108	80	86	243	427	200	139	411	542	439	463	3138
BOILERMAKERS	312	515	740	677	518	653	1225	2406	1940	1633	1785	12404
BRICKLAYERS	10	44	38	10	14	12	16	40	34	35	52	305
CARPENTERS	1589	1625	1180	1119	1174	1198	1347	1370	1103	974	973	13652
CEMENT MASONS	223	245	151	170	179	165	186	176	135	124	110	1864
ELECTRICIANS	1226	1613	1719	1704	1508	1244	1573	2652	2525	2063	1974	19802
IRON WORKERS	986	1095	906	771	728	828	1214	1306	1121	1112	1219	11286
LABORERS	1768	1990	1630	1713	1882	2004	2022	1976	1707	1406	1326	19424
MILLWRIGHTS	184	243	308	394	433	473	521	693	525	360	380	4515
OPERATING ENGINEERS	712	927	902	959	1098	1280	1349	1305	1072	944	946	11495
PAINTERS	146	190	162	177	197	202	172	178	156	132	107	1820
PIPEFITTERS	1868	2492	2243	2179	1852	1568	1568	2823	2559	2079	2199	23429
SHEETMETAL WORKERS	51	122	226	184	182	165	105	248	290	239	284	2097
TRUCK DRIVERS	382	632	613	524	498	463	466	415	338	288	276	4894
OTHERS	70	132	161	184	225	241	210	135	71	38	33	1503
TOTAL	9634	11945	11065	11008	10917	10699	12114	16134	14119	11866	12127	131628

TABLE 10 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=2 (NJ-NY)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	-20.3	395.4	-67.4	289.0	-14.6	400.1	1988
BOILERMAKERS	137.1	-29.9	136.2	58.4	-8.0	671.0	1987
BRICKLAYERS	276.3	-63.4	16.0	108.0	54.4	413.4	1990
CARPENTERS	-25.7	-0.5	14.8	-18.2	-11.8	2.3	1981
CEMENT MASONS	-32.2	18.4	4.1	-27.3	-18.9	10.0	1981
ELECTRICIANS	40.2	-12.3	4.3	60.6	-21.8	116.2	1987
IRON WORKERS	-8.1	-19.6	66.7	-7.6	8.8	32.5	1987
LABORERS	-7.8	15.5	7.4	-15.6	-22.3	14.3	1986
MILLWRIGHTS	67.8	40.6	20.2	0.9	-27.7	277.4	1987
OPERATING ENGINEERS	26.8	21.7	22.8	-20.5	-11.7	89.5	1986
PAINTERS	10.7	22.0	-12.7	-9.5	-31.1	38.5	1985
PIPEFITTERS	20.1	-17.4	-15.3	63.2	-14.1	51.1	1987
SHEETMETAL WORKERS	343.7	-19.5	-42.4	176.2	-1.9	468.7	1988
TRUCK DRIVERS	60.6	-18.8	-6.4	-27.4	-18.3	65.7	1981
OTHERS	129.0	39.4	-6.4	-66.0	-53.2	242.8	1985
TOTAL	14.9	-1.3	11.0	16.6	-14.1	67.5	1987

TABLE 11

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=3 (DE-DC-MD-PA-VA-WV)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	410	375	159	217	283	262	191	492	893	890	896	5069
BOILERMAKERS	1117	798	513	911	1406	929	1399	2890	3464	3892	3298	20616
BRICKLAYERS	30	21	20	28	35	26	31	74	64	64	40	434
CARPENTERS	1618	1494	1409	1608	1788	1564	1703	2109	2290	2133	1680	19396
CEMENT MASONS	260	208	203	223	240	235	230	262	287	268	200	2615
ELECTRICIANS	2907	2342	1637	1743	1830	1879	1892	3216	4087	4402	3754	29691
IRON WORKERS	1147	899	808	1051	1042	1050	1564	2196	2383	2207	1511	15857
LABORERS	2703	2500	2316	2978	2970	2619	2542	2971	3436	3210	2632	30879
MILLWRIGHTS	483	444	395	516	748	829	662	781	856	794	673	7182
OPERATING ENGINEERS	1392	1344	1377	1654	1736	1691	1741	2024	2221	1966	1575	18723
PAINTERS	314	279	231	225	330	351	261	302	383	316	225	3218
PIPEFITTERS	4056	3175	2359	2362	2529	2405	2070	3669	4562	4878	4301	36366
SHEETMETAL WORKERS	284	257	152	139	170	226	223	329	492	433	398	3103
TRUCK DRIVERS	799	646	597	783	803	688	593	704	822	774	653	7861
OTHERS	167	143	259	374	400	412	284	184	143	92	67	2525
TOTAL	17688	14925	12435	14811	16309	15166	15385	22205	26386	26321	21902	203533

TABLE 11 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=3 (DE-DC-MD-PA-VA-WV)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	-61.3	78.7	-32.8	368.6	0.3	118.6	1990
BOILERMAKERS	-54.1	174.1	-0.5	147.7	-4.8	248.6	1989
BRICKLAYERS	-32.3	71.7	-11.2	109.0	-38.5	149.8	1987
CARPENTERS	-13.0	26.9	-4.8	34.5	-26.6	41.5	1988
CEMENT MASONS	-22.2	18.5	-4.3	24.8	-30.1	10.2	1988
ELECTRICIANS	-43.7	11.8	3.4	116.0	-8.1	51.4	1989
IRON WORKERS	-29.5	28.9	50.1	52.4	-36.6	107.9	1988
LABORERS	-14.3	28.2	-14.4	35.2	-23.4	27.1	1988
MILLWRIGHTS	-18.2	89.4	-11.5	29.4	-21.4	77.3	1988
OPERATING ENGINEERS	-1.1	26.0	0.3	27.6	-29.1	59.5	1988
PAINTERS	-26.7	43.0	-20.7	46.7	-41.3	21.9	1988
PIPEFITTERS	-41.8	7.2	-18.1	120.4	-5.7	20.3	1989
SHEETMETAL WORKERS	-46.5	11.6	31.2	120.8	-19.1	73.0	1988
TRUCK DRIVERS	-25.2	34.5	-26.1	38.5	-20.5	2.9	1988
OTHERS	54.6	54.5	-28.9	-49.6	-53.6	146.0	1985
TOTAL	-29.7	31.2	-5.7	71.5	-17.0	49.2	1988

TABLE 12

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=4 (AL-FL-GA-KY-MS-NC-SC-TN)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	1414	1188	1017	1281	1187	844	1104	1516	1603	1517	1332	14004
BOILERMAKERS	5130	3381	4050	5088	4420	3872	6636	9113	9061	8072	7704	66529
BRICKLAYERS	253	210	213	187	178	202	287	339	358	268	291	2787
CARPENTERS	8954	7509	5417	4638	4385	4601	5681	6249	6620	6482	5889	66426
CEMENT MASONS	952	854	708	634	605	682	817	856	866	807	737	8518
ELECTRICIANS	9630	7854	6737	6756	6000	4625	5286	6978	7295	6721	6409	74290
IRON WORKERS	6195	5163	4174	3774	3122	3139	4179	4922	5088	5077	4590	49424
LABORERS	11412	10477	8245	7094	6496	5955	7101	8270	8377	7908	7398	88733
MILLWRIGHTS	1994	1566	1441	1508	1488	1329	1388	1633	1704	1619	1506	17177
OPERATING ENGINEERS	5925	5186	4383	3987	3685	3656	4760	5082	4863	4384	3993	49905
PAINTERS	1956	1759	1359	1331	1158	893	1021	1221	1353	1279	1148	14478
PIPEFITTERS	18885	15111	12315	11675	10123	7015	8533	11749	12738	11947	12261	132352
SHEETMETAL WORKERS	1140	1022	784	920	1004	632	635	996	1228	1163	959	10484
TRUCK DRIVERS	3257	2873	2398	2102	1817	1710	2240	2662	2558	2416	2149	26181
OTHERS	393	324	346	391	435	416	329	280	269	251	228	3659
TOTAL	77490	64477	53586	51367	46104	39571	49997	61868	63980	59912	56594	624946

TABLE 12 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=4 (AL-FL-GA-KY-MS-NC-SC-TN)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	-28.1	16.7	-7.0	45.2	-16.9	13.4	1988
BOILERMAKERS	-21.0	9.1	50.1	36.5	-15.0	77.6	1987
BRICKLAYERS	-15.7	-16.4	60.9	24.7	-18.8	41.4	1988
CARPENTERS	-39.5	-19.1	29.6	16.5	-11.0	0.0	1980
CEMENT MASONS	-25.6	-14.5	34.9	6.1	-14.9	0.0	1980
ELECTRICIANS	-30.0	-10.9	-11.9	38.0	-12.1	0.0	1980
IRON WORKERS	-32.6	-25.2	33.9	21.7	-9.8	0.0	1980
LABORERS	-27.8	-21.2	9.3	18.0	-11.7	0.0	1980
MILLWRIGHTS	-27.7	3.3	-6.7	22.7	-11.6	0.0	1980
OPERATING ENGINEERS	-26.0	-15.9	29.2	2.1	-17.9	0.0	1980
PAINTERS	-30.6	-14.8	-11.8	32.6	-15.2	0.0	1980
PIPEFITTERS	-34.8	-17.8	-15.7	49.3	-3.7	0.0	1980
SHEETMETAL WORKERS	-31.2	28.1	-36.7	93.3	-21.9	7.7	1988
TRUCK DRIVERS	-26.4	-24.2	23.3	14.2	-16.0	0.0	1980
OTHERS	-12.0	25.8	-24.4	-18.2	-15.4	10.7	1984
TOTAL	-30.8	-14.0	8.4	28.0	-11.5	0.0	1980

TABLE 13

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=5 (IL-IN-MI-MN-OH-WI)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	1225	1504	1307	1662	1717	1688	1615	923	1468	1479	1331	15920
BOILERMAKERS	3648	3369	4655	5443	4346	4211	3644	5138	6512	5920	6547	53433
BRICKLAYERS	215	150	177	148	163	141	160	155	118	108	100	1634
CARPENTERS	5763	5105	4604	3919	3729	3507	3776	4235	4197	3995	4197	47027
CEMENT MASONS	775	735	687	524	461	402	418	465	500	501	514	5980
ELECTRICIANS	9622	9522	9526	9231	7923	6347	5692	6186	8185	8784	9151	90170
IRON WORKERS	4717	4224	4403	3866	4236	3706	3656	4238	3891	3841	4092	44870
LABORERS	8092	7466	6955	6090	5718	5121	5268	5557	5864	5869	6058	68058
MILLWRIGHTS	1490	1515	1558	1644	1425	1237	1014	1027	1392	1357	1419	15079
OPERATING ENGINEERS	3863	3608	3684	3470	3319	2896	2945	3201	3338	3295	3423	37042
PAINTERS	1015	1107	1208	975	844	902	713	559	549	541	554	8968
PIPEFITTERS	13245	13458	13159	12077	9779	8379	7139	7365	9880	9614	10109	114203
SHEETMETAL WORKERS	1098	996	941	1142	1011	976	688	580	790	773	803	9796
TRUCK DRIVERS	1903	1726	1625	1405	1249	1133	1139	1078	1156	1045	1033	14492
OTHERS	213	200	186	153	142	125	125	125	125	121	117	1631
TOTAL	56884	54685	54675	51748	46061	40771	37992	40832	47967	47242	49447	528302

TABLE 13 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=5 (IL-IN-MI-MN-OH-WI)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	6.7	31.4	-6.0	-9.1	-9.3	40.2	1984
BOILERMAKERS	27.6	-6.6	-16.1	78.7	0.5	79.5	1990
BRICKLAYERS	-17.5	-8.1	-2.1	-26.2	-15.5	0.0	1980
CARPENTERS	-20.1	-19.0	1.3	11.2	-0.0	0.0	1980
CEMENT MASONS	-11.3	-32.9	-9.4	19.7	2.7	0.0	1980
ELECTRICIANS	-1.0	-16.8	-28.2	43.8	11.8	0.0	1980
IRON WORKERS	-6.7	-3.8	-13.7	6.4	5.1	0.0	1980
LABORERS	-14.1	-17.8	-7.9	11.3	3.3	0.0	1980
MILLWRIGHTS	4.6	-8.5	-28.8	37.2	2.0	10.3	1983
OPERATING ENGINEERS	-4.6	-9.9	-11.3	13.4	2.5	0.0	1980
PAINTERS	19.0	-30.2	-15.5	-22.9	0.8	19.0	1982
PIPEFITTERS	-0.6	-25.7	-27.0	38.4	2.3	1.6	1981
SHEETMETAL WORKERS	-14.3	7.5	-32.0	14.8	1.6	4.0	1983
TRUCK DRIVERS	-14.6	-23.2	-8.8	1.5	-10.6	0.0	1980
OTHERS	-12.7	-23.5	-12.1	0.2	-6.2	0.0	1980
TOTAL	-3.9	-15.8	-17.5	26.3	3.1	0.0	1980

TABLE 14

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=6 (AR-LA-NM-OK-TX)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	1122	1142	979	727	1227	1141	914	998	1119	1962	1510	12841
BOILERMAKERS	5596	4230	2811	5278	6971	6124	5776	4857	7239	9232	8208	66321
BRICKLAYERS	225	142	167	247	233	246	221	295	268	327	309	2680
CARPENTERS	4205	3617	4125	5001	5548	5238	4727	5263	5852	6040	5405	55022
CEMENT MASONS	582	512	579	690	778	792	745	816	945	944	890	8275
ELECTRICIANS	6978	6332	4388	3716	6022	6060	5785	6370	6046	9186	6916	67798
IRON WORKERS	3672	2821	2932	3849	4357	4172	3494	3795	4516	4861	4563	43032
LABORERS	6120	5578	5349	6074	7150	6631	6288	6570	7666	8579	7834	73840
MILLWRIGHTS	1351	1231	847	851	1236	1271	1199	1208	1464	2008	1718	14384
OPERATING ENGINEERS	3339	3097	2886	3515	3883	3417	3445	3502	4656	4962	4523	41225
PAINTERS	1191	1141	820	717	964	934	855	860	935	1268	1207	10892
PIPEFITTERS	12230	10395	6746	6150	9670	9639	9128	9406	8949	14005	10702	107020
SHEETMETAL WORKERS	887	1012	717	385	848	888	780	939	712	1299	1067	9533
TRUCK DRIVERS	1932	1545	1329	1625	1838	1902	1982	2109	2510	2495	2287	21554
OTHERS	206	164	158	183	200	205	224	297	384	393	319	2731
TOTAL	49636	42957	34833	39009	50925	48661	45564	47285	53261	67560	57459	537148

TABLE 14 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=6 (AR-LA-NM-OK-TX)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	-12.7	25.3	-25.5	22.4	35.0	74.9	1989
BOILERMAKERS	-49.8	148.0	-17.1	25.3	13.4	65.0	1989
BRICKLAYERS	-26.0	39.8	-5.1	21.0	15.6	45.2	1989
CARPENTERS	-1.9	34.5	-14.8	23.8	-7.6	43.6	1989
CEMENT MASONS	-0.6	34.4	-4.2	26.8	-5.8	62.3	1988
ELECTRICIANS	-37.1	37.2	-3.9	4.5	14.4	31.6	1989
IRON WORKERS	-20.1	48.6	-19.8	29.2	1.0	32.4	1989
LABORERS	-12.6	33.7	-12.1	21.9	2.2	40.2	1989
MILLWRIGHTS	-37.3	45.9	-3.0	22.1	17.4	48.6	1989
OPERATING ENGINEERS	-13.6	34.5	-11.3	35.1	-2.9	48.6	1989
PAINTERS	-31.2	17.6	-11.3	9.3	29.2	6.4	1989
PIPEFITTERS	-44.8	43.3	-5.6	-2.0	19.6	14.5	1989
SHEETMETAL WORKERS	-19.2	18.3	-8.0	-8.7	49.9	46.4	1989
TRUCK DRIVERS	-31.2	38.3	7.8	26.6	-8.9	29.9	1988
OTHERS	-23.1	26.5	12.1	71.6	-17.0	91.0	1989
TOTAL	-29.8	46.2	-10.5	16.9	7.9	36.1	1989

TABLE 15

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=7 (IA-KS-MO-NE)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	667	819	732	381	417	404	203	84	244	141	39	4131
BOILERMAKERS	2432	2115	1455	1452	1725	1162	483	893	1001	497	524	13741
BRICKLAYERS	102	70	51	38	29	22	8	14	15	39	45	434
CARPENTERS	2128	1476	1205	1189	1016	524	390	697	870	1089	1240	11825
CEMENT MASONS	287	197	159	140	127	67	43	65	74	98	120	1377
ELECTRICIANS	4418	3960	2540	1659	1969	1486	743	925	1136	809	861	20504
IRON WORKERS	2136	1565	1228	1193	1014	496	404	674	644	681	825	10859
LABORERS	3178	2439	2032	1660	1448	873	590	920	1194	1431	1615	17381
MILLWRIGHTS	776	731	520	390	502	325	106	153	236	219	269	4228
OPERATING ENGINEERS	1853	1290	1086	1066	930	543	321	553	688	746	840	9917
PAINTERS	415	458	504	198	146	117	56	51	48	57	96	2146
PIPEFITTERS	5816	5524	3695	1871	2200	1650	728	1004	1293	846	1038	25665
SHEETMETAL WORKERS	506	540	270	225	240	157	87	49	114	65	38	2291
TRUCK DRIVERS	786	617	508	372	374	244	121	180	238	286	318	4043
OTHERS	134	80	105	130	125	39	14	47	90	154	185	1102
TOTAL	25633	21881	16091	11965	12261	8110	4298	6309	7884	7158	8054	129645

TABLE 15 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=7 (IA-KS-MO-NE)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	9.8	-43.0	-51.4	20.3	-83.8	22.9	1981
BOILERMAKERS	-40.2	18.5	-72.0	107.1	-47.7	0.0	1980
BRICKLAYERS	-49.4	-44.6	-71.8	88.0	196.7	0.0	1980
CARPENTERS	-43.4	-15.7	-61.6	123.1	42.5	0.0	1980
CEMENT MASONS	-44.6	-20.0	-66.0	70.3	63.4	0.0	1980
ELECTRICIANS	-42.5	-22.5	-62.3	52.9	-24.2	0.0	1980
IRON WORKERS	-42.5	-17.4	-60.2	59.3	28.1	0.0	1980
LABORERS	-36.1	-28.7	-59.3	102.5	35.2	0.0	1980
MILLWRIGHTS	-33.1	-3.4	-78.9	122.4	14.2	0.0	1980
OPERATING ENGINEERS	-41.4	-14.4	-65.4	114.2	22.0	0.0	1980
PAINTERS	21.3	-71.1	-61.7	-14.4	101.4	21.3	1982
PIPEFITTERS	-36.5	-40.5	-66.9	77.6	-19.7	0.0	1980
SHEETMETAL WORKERS	-46.7	-11.1	-63.6	30.3	-66.4	6.6	1981
TRUCK DRIVERS	-35.3	-26.4	-67.7	96.6	33.5	0.0	1980
OTHERS	-21.1	18.4	-88.5	524.1	106.7	38.6	1990
TOTAL	-37.2	-23.8	-64.9	83.4	2.2	0.0	1980

TABLE 16

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=8 (CO-MT-ND-SD-UT-WY)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	494	814	1332	1257	668	490	578	657	503	902	473	8169
BOILERMAKERS	2149	4082	5126	3034	1759	2075	2524	2405	3240	3115	1949	31458
BRICKLAYERS	85	91	112	65	44	46	38	40	45	36	23	625
CARPENTERS	1967	2783	2601	1695	1349	1370	1363	1605	1756	1477	1308	19275
CEMENT MASONS	228	313	294	183	158	156	159	184	213	164	163	2214
ELECTRICIANS	2487	4384	5669	4106	2464	2385	2880	3047	3611	3757	2802	37590
IRON WORKERS	2264	3278	2820	1841	1442	1522	1422	1615	1871	1297	1372	20745
LABORERS	2677	4116	3875	3368	2615	2071	1925	2249	2419	2217	1927	29459
MILLWRIGHTS	564	857	1139	780	487	465	509	503	593	673	383	6954
OPERATING ENGINEERS	2079	2808	2715	1995	1581	1289	1207	1367	1448	1286	1075	18850
PAINTERS	209	352	358	321	209	194	179	175	198	166	148	2509
PIPEFITTERS	2738	4816	6584	4358	2612	2636	3165	3217	3742	4142	2542	40552
SHEETMETAL WORKERS	320	626	667	619	297	278	310	289	304	400	207	4318
TRUCK DRIVERS	598	844	992	793	624	443	388	408	419	412	317	6237
OTHERS	121	96	83	57	43	42	41	47	47	41	36	653
TOTAL	18980	30262	34367	24473	16351	15461	16689	17808	20408	20084	14726	229609

TABLE 16 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=8 (CO-MT-ND-SD-UT-WY)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	169.5	-49.9	-13.6	-12.9	-6.0	169.5	1982
BOILERMAKERS	138.6	-65.7	43.5	28.4	-39.8	138.6	1982
BRICKLAYERS	31.7	-60.4	-13.0	16.0	-47.4	31.7	1982
CARPENTERS	32.2	-48.1	1.1	28.9	-25.5	41.5	1981
CEMENT MASONS	29.0	-46.2	0.7	33.8	-23.4	37.7	1981
ELECTRICIANS	127.9	-56.5	16.9	25.4	-22.4	127.9	1982
IRON WORKERS	24.6	-48.9	-1.4	31.5	-26.7	44.8	1981
LABORERS	44.8	-32.5	-26.4	25.7	-20.3	53.8	1981
MILLWRIGHTS	101.8	-57.3	4.6	16.4	-35.4	101.8	1982
OPERATING ENGINEERS	30.6	-41.8	-23.6	19.9	-25.7	35.1	1981
PAINTERS	71.2	-41.8	-14.3	10.9	-25.4	71.2	1982
PIPEFITTERS	140.5	-60.3	21.1	18.2	-32.1	140.5	1982
SHEETMETAL WORKERS	108.4	-55.5	4.5	-2.0	-31.8	108.4	1982
TRUCK DRIVERS	65.9	-37.1	-37.9	8.0	-24.3	65.9	1982
OTHERS	-31.9	-48.2	-5.1	16.1	-22.6	0.0	1980
TOTAL	81.1	-52.4	2.1	22.3	-27.8	81.1	1982

TABLE 17

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=9 (AZ-CA-HI-NV)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	539	525	458	377	737	995	736	331	378	548	451	6076
BOILERMAKERS	1531	1464	1448	2391	3969	4221	2064	1301	1531	1627	1375	22921
BRICKLAYERS	80	57	63	53	85	81	60	50	51	48	45	674
CARPENTERS	2387	1686	1705	2053	2518	1952	980	798	930	895	743	16647
CEMENT MASONS	301	232	220	224	302	223	120	87	108	100	88	2006
ELECTRICIANS	4012	3358	2777	3011	4364	4638	2705	1417	1574	1866	1547	31270
IRON WORKERS	1894	1417	1646	2054	2571	1886	1064	1057	1194	1162	951	16894
LABORERS	4067	3800	3439	3426	4630	3229	1671	1099	1236	1211	1023	28831
MILLWRIGHTS	829	803	568	547	850	958	510	277	324	370	317	6351
OPERATING ENGINEERS	2168	1945	2002	2129	2545	1847	1067	788	942	844	741	17017
PAINTERS	648	562	484	292	365	397	151	111	125	154	137	3425
PIPEFITTERS	5783	5159	3613	4026	5483	5607	3097	1633	1925	2121	1878	40324
SHEETMETAL WORKERS	370	347	236	318	363	506	289	227	251	324	225	3457
TRUCK DRIVERS	1054	990	886	934	1160	949	532	275	307	311	280	7679
OTHERS	219	157	86	106	138	125	60	34	37	36	31	1028
TOTAL	25882	22500	19632	21942	30079	27613	15107	9484	10912	11616	9831	204598

TABLE 17 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=9 (AZ-CA-HI-NV)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	-15.0	60.8	-0.2	-48.6	19.3	84.5	1985
BOILERMAKERS	-5.4	174.1	-48.0	-25.8	-10.2	175.7	1985
BRICKLAYERS	-20.9	33.5	-28.5	-15.9	-11.4	5.6	1984
CARPENTERS	-28.6	47.6	-61.1	-5.1	-20.1	5.5	1984
CEMENT MASONS	-26.7	37.1	-60.4	-9.9	-18.0	0.5	1984
ELECTRICIANS	-30.8	57.1	-38.0	-41.8	-1.7	15.6	1985
IRON WORKERS	-13.1	56.2	-58.6	12.2	-20.4	35.7	1984
LABORERS	-15.5	34.7	-63.9	-26.0	-17.3	13.9	1984
MILLWRIGHTS	-31.5	49.7	-39.9	-36.6	-2.1	15.5	1985
OPERATING ENGINEERS	-7.7	27.2	-58.1	-11.8	-21.3	17.4	1984
PAINTERS	-25.3	-24.7	-58.6	-17.1	9.0	0.0	1980
PIPEFITTERS	-37.5	51.8	-43.5	-37.8	-2.5	0.0	1980
SHEETMETAL WORKERS	-36.2	53.6	-20.2	-13.2	-10.4	36.7	1985
TRUCK DRIVERS	-15.9	30.9	-54.1	-42.3	-8.8	10.1	1984
OTHERS	-60.8	60.1	-56.5	-39.0	-16.1	0.0	1980
TOTAL	-24.1	53.2	-49.8	-27.8	-9.9	16.2	1984

TABLE 18

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=REGION 10 (AK-ID-OR-WA)

	TOTAL ANNUAL REQUIREMENTS (THOUSANDS OF WORKHOURS)											
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
ASBESTOS WORKERS	243	279	197	242	159	51	83	176	461	603	643	3135
BOILERMAKERS	1047	825	351	369	456	573	658	850	1120	1188	924	8360
BRICKLAYERS	91	60	36	59	48	84	64	57	66	42	26	634
CARPENTERS	2622	1976	1413	1945	2275	2315	2129	1858	1589	1331	922	20375
CEMENT MASONS	319	269	139	174	230	273	280	301	262	222	153	2622
ELECTRICIANS	3510	3832	1854	1506	1415	1827	2625	3212	3817	3352	2522	29471
IRON WORKERS	1816	1445	1009	1337	1540	1529	1441	1424	1417	1239	895	15092
LABORERS	4342	3228	2137	2806	2830	2700	2542	2494	2445	2188	1588	29299
MILLWRIGHTS	671	583	287	247	211	236	325	480	596	596	469	4701
OPERATING ENGINEERS	2061	1586	1013	1154	1104	1077	1038	1180	1164	1079	787	13242
PAINTERS	406	442	261	349	318	218	284	347	406	512	352	3894
PIPEFITTERS	4926	5515	2867	2555	2232	2960	3711	4765	5225	4779	3497	43031
SHEETMETAL WORKERS	266	356	167	123	73	95	216	286	443	433	311	2769
TRUCK DRIVERS	959	635	362	419	450	541	662	671	721	555	384	6360
OTHERS	185	86	31	33	46	58	81	77	87	59	44	786
TOTAL	23464	21116	12123	13317	13386	14537	16138	18179	19819	18178	13515	183773

TABLE 18 (continued)

ONSITE MANUAL CONSTRUCTION LABOR REQUIREMENTS
FOR ELECTRIC POWER PLANTS, BY CRAFT, 1980-1990
ALL OWNERSHIP
REPORT (S-110)
REGION=REGION 10 (AK-ID-OR-WA)

	PERCENT CHANGE						
	80-82	82-84	84-86	86-88	88-90	80-PEAK	PEAK YR
ASBESTOS WORKERS	-19.0	-19.2	-48.0	456.4	39.6	164.3	1990
BOILERMAKERS	-66.4	29.7	44.5	70.2	-17.5	13.5	1989
BRICKLAYERS	-60.0	32.9	31.9	4.5	-60.4	0.0	1980
CARPENTERS	-46.1	61.0	-6.4	-25.3	-42.0	0.0	1980
CEMENT MASONS	-56.5	65.7	21.7	-6.3	-41.7	0.0	1980
ELECTRICIANS	-47.2	-23.7	85.6	45.4	-33.9	9.2	1981
IRON WORKERS	-44.4	52.7	-6.4	-1.7	-36.9	0.0	1980
LABORERS	-50.8	32.4	-10.2	-3.8	-35.0	0.0	1980
MILLWRIGHTS	-57.2	-26.6	53.9	83.6	-21.3	0.0	1980
OPERATING ENGINEERS	-50.9	9.0	-5.9	12.1	-32.4	0.0	1980
PAINTERS	-35.7	22.1	-10.8	43.0	-13.2	26.3	1989
PIPEFITTERS	-41.8	-22.2	66.3	40.8	-33.1	11.9	1981
SHEETMETAL WORKERS	-37.4	-56.1	195.3	104.9	-29.9	66.3	1988
TRUCK DRIVERS	-62.2	24.3	47.1	8.9	-46.8	0.0	1980
OTHERS	-83.3	47.9	76.7	7.1	-49.2	0.0	1980
TOTAL	-48.3	10.4	20.6	22.8	-31.8	0.0	1980

Figure 11

U.S. DEPARTMENT OF LABOR
FEDERAL REGIONS[1]

Figure 11 (continued)

Region	States
I:	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
II:	New Jersey, New York
III:	Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia
IV:	Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee
V:	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin
VI:	Arkansas, Louisiana, New Mexico, Oklahoma, Texas
VII:	Iowa, Kansas, Missouri, Nebraska
VIII:	Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming
IX:	Arizona, California, Hawaii, Nevada
X:	Alaska, Idaho, Oregon, Washington

national total during the period, the Great Plains Region (Region VII), which is expected to decline from 8 percent to 3.3 percent of the national total and the Pacific West (Region IX) which is projected to fall from 8.1 percent to 4.0 percent. The primary explanation for this decline is the relatively low rate of population and industrial growth expected in these regions, which makes the demand for electric generation more closely geared to replacement requirements.

The Southwest (Region VI) is expected to have the largest gain relative to the national total. This Region's labor requirements are projected to rise from 15.4 percent of the national total in 1980 to 23.4 percent in 1990, and the Region will rise from 3rd place to 1st place as the nation's most important region in terms of construction labor requirements associated with powerplants.

Substantial gains relative to the nation are also expected in the Middle Atlantic Region (III) which made up 5.5 percent of the 1980 total, ranking eighth, and is projected to increase to 8.9 percent and fourth place rank by 1990.

Examination of the detail for crafts among the regions shows that the relative importance of a particular craft varies from region to region and from year to year. The most fundamental reasons for these variations are shifts among the different types of generating units (nuclear, coal, hydro, gas and oil) and the phase of construction, which requires different craft concentrations at different construction stages. In general, laborers and operating engineers are utilized most heavily at the beginning of a powerplant project; pipefitters, boilermakers and electricians reach peaks during the middle phases of construction; and asbestos workers and painters are concentrated most heavily in the final stages of a project.

In New England (Region I) there are substantial declines in labor requirements for most trades in each year through 1988. Peak requirements in each trade are reached in the first three years of the period, and the overall decline in labor demand is 87 percent of the initial total. The decline is substantially the same across all occupations.

Region II (New York-New Jersey) has generally increasing labor demand until 1987 and declining labor requirements thereafter, with an overall increase of 26 percent. The largest increases are for boilermakers, sheet metal workers, bricklayers, and asbestos workers, and the greatest decreases are for cement masons, carpenters, and truck drivers.

The Middle Atlantic (Region III) reaches its low point in 1982 and increases labor requirements by 24 percent over the decade. Demand for boilermakers and asbestos workers more than doubles, and there are substantial gains for sheet metal workers, millwrights, and iron workers. There is reduced demand in four occupations, with the greatest declines for painters and cement masons.

The southeast (Region IV) has a decline in labor requirements until 1985, recovery through 1988, and two years of decline to a 1990 level 27 percent lower than 1980. Boilermakers and bricklayers are the only trades expected to increase in demand and the greatest relative declines are for painters and pipefitters, expected to fall by 41 and 35 percent, respectively.

In the Great Lakes Region (V) labor requirement fall each year, reaching a trough in 1986, 33 percent below the 1980 figure. Some recovery in the final four years brings the 1990 requirements to a level 30 percent higher than 1986, and only 13 percent lower than 1980. There is increased demand for boilermakers and asbestos workers, and the declines for bricklayers, truck drivers and painters are all more than three times as steep as the decline for labor in general.

Labor requirements in the Southwest (Region VI) rise in five years and fall in five years, but finish the decade 16 percent higher than the 1980 level. Pipefitters and electricians are the only trades with a projected decline during the period, and cement masons and boilermakers have the largest rates of increase.

With the exception of New England, the Plains area (Region VII) has the sharpest rate of decline in construction labor requirements. Declines in every year bring the 1986 total to only 16.7 percent of the 1980 figure, and even an 87 percent increase from 1986 to 1990 leaves the 1990 requirements 68.6 percent lower than 1980. The decline extends to every trade, and is relatively highest for asbestos workers and sheet metal workers, both declining more than 90 percent.

The Rocky Mountain States (Region VIII) reach peak demand in 1982, when the total is 81 percent higher than in 1980. From 1982 through 1990 there are consistent declines, and the 1990 total, 22 percent lower than 1980 and 57 percent lower than 1982, was the lowest of the decade. Electricians are the only trade to increase labor requirements from 1980 to 1990, and the largest declines are for bricklayers, operating engineers, and truck drivers.

In the Pacific Coast Region (IX) there are unusually wide year-to-year changes in the projections, and peak requirements in 1984 are 217 percent higher than those at the trough in 1987. A decline of 62 percent is projected between 1980 and 1990, a decline exceeded only by New England and the Plains. The decline extends to every occupation, and exceeds 70 percent for painters, laborers, truck drivers, and cement masons.

The Pacific Northwest (Region X) has an overall decrease in labor requirements amounting to 42 percent. Demand is expected to decline sharply until 1983, when it reaches its low point for the decade at 43 percent below the 1980 level. There is increased demand for asbestos workers and sheet metal workers in contrast to declines for all other trades. Declines are particularly large for bricklayers, carpenters, and laborers.

Footnotes

1 Capital cost is defined for the purpose of this study as total investment cost net of escalation, i.e. plant cost, land cost, home office cost (including taxes, fees, contingencies, etc.), design cost and interest during construction converted to 1980 dollars. (See Appendix D for a technical explanation of the cash flow conversion.) Construction labor requirements include all direct and indirect on-site manual labor hours.

2 United Nations Association of the United States of America, Energy and Employment: Issues and an Agenda for Research, A Report for the Energy and Jobs Panel of the Economic Policy Council, UNA-USA, June 1979.

3 For a detailed description of the Construction Labor Demand System (CLDS), see William F. Hahn and William R. Schriver, An Overview of the Construction Industry and the Development of CLDS, Working Paper 11, ESA, U. S. Department of Labor, 1981.

4 It is recognized that the TMI accident and discoveries of other design problems may increase the capital costs of future plants, those currently under construction and even those currently in operation. While one can explain historical cost increases on this basis (see Paik and Schriver, Op.cit.), forecasts of these events would be conjectural at best.

5 It should be noted that the impact of scrubbers on the craft mix required to construct fossil powerplants was assumed to be neutral across all crafts while in fact some crafts, such as pipefitters, electricians and boilermakers, are more heavily utilized on fossil plants with scrubbers. Therefore, the results of this study will slightly underestimate the true demands for these crafts.

[6] For a thorough treatment of the effect of increased regulation on capital costs of nuclear powerplants, see Soon Paik and William R. Schriver, "The Effect of Increased Regulation on Capital Costs and Manual Labor Requirements of Nuclear Powerplants," The Engineering Economist, Vol. 26, No. 3, Spring 1981.

[7] For a discussion of this topic, see U. S. Department of Energy, Nuclear Energy Division, A Review of the Economics of Coal and Nuclear Power, 1981.

Appendix A: Technical Note

I. Forecasting Models

The Construction Labor Demand System (CLDS) provides estimates of ongoing construction activity as well as forecasts of future construction activity and related on-site manual labor requirements in local regions. The construction of electric powerplants includes the following types of electric generating facilities:

- Nuclear Powerplants

  Boiling Water Reactor (BWR)
  Pressurized Water Reactor (PWR)

- Fossil-Fired Powerplants

  Coal-Fired
  Oil-Fired
  Gas-Fired

- Hydroelectric Powerplants

  Concrete Dam
  Earth Dam
  Generating Unit Addition
  Pump Storage

The time horizon for the powerplant forecast is 10 years, and the system generates forecasts by state and U.S. Department of Labor region. The mathematical expression of the forecasting model for 15 on-site manual labor requirements is:

$$(WH_j)_{rt} = \sum_i \sum_q \sum_{T=t-D-1}^{t} \left[Q^D_{iqrT} \cdot L_{iqrT} \cdot (A_j)^{t(T,D)}_{iqr} \right] \qquad (A1)$$

where $(WH_j)_{rt}$ = a column vector of manual construction labor requirements at t-th calendar month in region r, j = 1st, 2nd,... 15th craft,

Q^D_{iqrT} = electric generating capacity (KWe) of the ith type of powerplant with size q, starting construction from Tth calendar month in region r, whose construction duration is D months,

L_{iqrT} = unit construction labor requirements (WH/Kwe) corresponding to each Q^D_{iqrT} ,

$(A_j)^{t(T,D)}_{iqr}$ = (15x1) occupational profile column vector at month t corresponding to each Q^D_{iqrT} , where t depends on T and D.

For the present forecasts, the occupational profile (A) is assumed to be stable over the period of time. The capacity addition of electric powerplants (Q), including planned and forecasted projects and unit construction labor requirements (WH/KWe), are forecasted.

II. Electric Powerplant Projects

The electric powerplant file includes two classes of powerplant projects: planned projects and forecasted projects. The planned powerplant projects are obtained from three sources: (1) Inventory of Powerplants in the United States, U. S. Department of Energy, Energy Information Administration, Washington, D.C., 1981, (2) U.S. Central Station Nuclear Electric Generating Units: Significant Milestones, U.S. Department of Energy, Office of Nuclear Reactor Programs, Washington, D.C., March 1981, and (3) Nuclear Powerplants:Construction Status Report, U. S. Nuclear Regulatory Commission, NUREG-0030, Vol. 4, Washington, D.C., April 1981. The Electric Powerplant Project Forecasting System provides estimates of the added capacity required to meet forecasted electric generation, which would not be covered by planned powerplant projects.

The forecasted powerplant projects are based on the prediction of installed electric generating capacity provided by the U. S. Department of Energy - Energy Information Administration's 1981 Annual Report to Congress.
This report produces projections for the bench-mark years (1985, 1990, 1995) of regional "available new" electric generating capacity by fuel type (See Tables A1 and A2). "Available new" capacity includes new capacity additions required to meet forecasted electric generation during the period after plant retirements, upgrading, downgrading, and conversions are taken into account. New additions of electric generating capacity of type i in region r at year t (Q^N_{irt}) above planned projects are generated from the "available new" capacity prediction by the following equation:

$$Q^N_{irt(j)} = Q^N_{ir\bar{t}(j)} + \Delta_{irt} \left(Q^N_{ir\bar{t}(j+1)}\right) - \sum_n Q^P_{irtn} \qquad \text{(A2)}$$

Table A 1

Forecasts of Electric Utility Generating Capacity

(Gigawatts)

Type	1985	1990	1995
Coal	48.25*	96.95	192.59
Oil	8.82	9.78	13.19
N. Gas	1.42	1.65	1.65
Hydro	6.12	6.86	6.86
Pump-Storage	3.47	12.48	14.12
Others	2.69	5.52	9.37
Total	70.77	133.24	217.76

NOTE: * "Available new" capacity additions estimated with inclusion of retirements, replacements, and conversion (updating) on the basis of January 1, 1979, capacity.

SOURCE: U. S. DOE/EIA's 1981 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13.

Table A 2

Cumulative LWR Electric Generating Capacity Forecasts Through 2000
(Gigawatts Electric)

Year[a]	1980	1985	1990	1995	2000
MEFS[b]	53	85	118	132	NA
CLDS[c]	53	110	126	135	142

NOTE:

a. Capacity estimates at the end of year.

b. Based on U. S. DOE/EIA's 1981 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13.

c. Based on U. S. NRC's Nuclear Powerplants Construction Status Report, NUREG-0030, Vol. 4, April 1981, and U. S. DOE's Central Station Nuclear Electric Generating Units: Significant Milestones, September 1981.

where $Q^N_{ir\bar{t}(j)}$ = annual new capacity addition averaged during the period from j-1 to j, calculated from the "available new" capacities of bench-mark years j-1 and j, $\bar{t}$ is the midpoint between j-1 and j,

Δ_{irt} = a smoothing term which is dependent on average annual new capacity addition in the next period,

Q^P_{irtn} = the n planned projects of type i, in region r, in year t.

In order to forecast new additions of electric powerplant projects, one must have information concerning calendar month of construction start, construction duration, and project size, in addition to project type and location. The functions of project size distribution and construction start distribution are utilized for generating an added powerplant project of type i, located in region r with size q starting construction from calendar month m (Q^N_{irqm}) from the forecasted new additions of electric generating capacity (Q^N_{irt}) as follows:

$$Q^N_{irqm} = Q^N_{irt} \cdot Z_{ir} \cdot M_{ir} \quad \text{(A3)}$$

where Z_{ir} = project size distribution function of ith type in region r,

M_{ir} = function distributing calendar month of construction start reflecting seasonal pattern of construction activity for ith type in region r.

The Z function is estimated from historical data on powerplant projects provided from U. S. Department of Energy, Energy Information Administration's Inventory of Powerplants in the United States (1981), while the F. W. Dodge Construction Potentials files of 1972 through 1979 are the basis for the estimation of the M function. The estimated Z and M functions are shown in Tables A3 and A4, respectively.

Table A 3

Project Size Distribution for Electric Powerplants by Type

Type	Size (MWe)	Percent (%)
Nuclear (LWR)	1000	100
		100
Coal-Fired	1-300	30
	301-600	40
	600-	30
		100
Oil-Fired	1-300	40
	301-600	40
	600-	20
		100
Gas-Fired	1-300	100
		100
Hydro-Dam	1-200	50
	201-	50
		100
Pump-Storage	1-400	60
	401-	40
		100

Table A 4

Quarterly Distribution of Electric
Powerplant Project Starts

Region[a]	Winter[b]	Spring	Summer	Fall
North	100[c]	110	150	120
South	100	100	140	100

Note:

a. North = U. S. DOL Regions I, II, III, V, VII, VIII, IX, X

South = U.S. DOL Region IV, VI.

b. Winter Quarter = January, February, March,
Spring Quarter = April, May, June,
Summer Quarter = July, August, September,
Fall Quarter = October, November, December.

c. Indices (Winter Quarter = 100).

III. Estimation of Construction Labor Requirement and Cost Functions

A. Labor Requirement Functions

There are two conceptual models applied in estimating the construction labor requirement functions: one is derived from the production function and the other from the construction cost equation.

A.1. Derived Labor Requirement Function

In order to estimate construction workhour requirements, especially for the construction of electric powerplants, it is necessary to consider the interaction of two major factors: (1) economies of scale and (2) exogeneous forces affecting powerplant construction. To capture these aspects, let us consider a production function having two production inputs, labor (L) and capital (K) in the following form:

$$V = F\ (L,K: \lambda) \qquad \text{(A4)}$$

where V is the value of real construction output, measured in MWe capacity, and λ is a vector of exogeneous forces. Assuming λ affects labor and capital symmetrically, then the construction production function (A4) can be rewritten as follows:

$$V = G\left[\delta_1\ (\lambda)\ L,\ \delta_2\ (\lambda)\ K\right] \qquad \text{(A5)}$$

where δ_1 and δ_2 both are functions of λ alone, and $\delta_1\ (\lambda)\ L$ and $\delta_2(\lambda)\ K$ are the "augmented" labor and the "augmented" capital inputs, respectively. The construction labor requirement function then can be derived from the production function (A5) by solving for the labor required as a function of construction output and augumented capital services:

$$L^* = G^{-1}(V,K^*) \qquad \text{(A6)}$$

where $L^* = \delta_1(\lambda)L$, $K^* = \delta_2(\lambda)K$, and G^{-1} is the inverse of the production function (A5). Here, V is the construction output which embeds all the impacts of exogeneous forces (λ), even though it is measured in MWe capacity.

We utilize both linear and non-linear forms of the construction labor requirement function such as:

$$L^* = d_o + d_1 \text{ MWe} \tag{A7}$$

$$L^* = d_o \cdot MW_e^{d_1} \tag{A8}$$

A.2. The relationship between Construction Labor and Plant Cost.

In order to identify and isolate the portion of power-plant cost increases contributing to increasing labor requirements, consider the following cost equations for construction:

$$C = W \cdot L + P_m \cdot M + P_e \cdot E \tag{A9}$$

where
- C = total plant costs;
- L = total construction labor;
- M = total construction materials;
- E = total construction equipment;
- W = wage rates;
- P_m = prices of construction materials;
- P_e = prices of construction equipment.

Taking the total differential of equation (A9) and expressing it in a percentage change form gives:

$$dC/C = (dW/W) \cdot \alpha + (dP_m/P_m) \cdot \beta + (dP_e/P_e) \cdot \gamma \tag{A10}$$
$$+ (dL/L) \cdot \alpha + (dM/M) \cdot \beta + (dE/E) \cdot \gamma$$

where $\alpha = (W \cdot L)/C$; $\beta = (P_m \cdot M)/C$; $\gamma = (P_e \cdot E)/C$.

The first three terms on the right-hand side of equation (A10) represent the rates of inflation of the three input factors, and the last three terms indicate the rates of their physical requirement increases due to increases in the scope of work of the construction. What equation (A10) in fact implies is that changes in total plant costs can be explained by price changes of input factors and their volume changes, both of which are weighted by the factors' respective cost shares.

Equation (A10) can be rewritten as:

$$(dC/C - i) = (dL/L) \cdot \alpha + (dM/M) \cdot \beta + (dE/E) \cdot \gamma \qquad \text{(A11)}$$

where $i = (dW/W) \cdot \alpha + (dP_m/P_m) \cdot \beta + (dP_e/P_e) \cdot \gamma$

From equation (A11), one can derive the following labor-cost relation:

$$dL/L = \left[(1 - Y - Z) \; / \alpha\right] \cdot (dC/C - i) \qquad \text{(A12)}$$

where $Y = \left[(dM/M) \cdot \beta\right] / \left[(dC/C) - i\right]$,

$Z = \left[(dE/E) \cdot \gamma\right] / \left[(dC/C) - i\right]$.

Equation (A12) implies that the rate of change in construction labor requirements equals the weighted rate of change in plant cost in constant dollars. The weight is composed of two factors: labor's importance in cost changes and the wage bill's share of total costs.

Equation (A12) can be expressed in terms of logarithmic differentials as follows:

$$d\,(\mathrm{Log}\ L) = e_1\, d(\mathrm{Log}\ C^*) \qquad \text{(A13)}$$

where $e_1 = (1 - Y - Z)/\alpha$;

C^* = total plant costs in constant dollars.

Therefore, the statistical construction labor-plant cost relation is specified as the equation (A14):

$$\mathrm{Log}\ L = e_o + e_1\ \mathrm{Log}\ C^* \qquad \text{(A14)}$$

where e_o and e_1 are coefficients to be estimated.

B. Capital Cost Functions

A general form of plant cost function for the construction of electric powerplants can be written as follows:

$$C = F\,(MWe, \underline{P}, \underline{Z}) \qquad \text{(A15)}$$

where C = total capital costs for constructing electric powerplants;

MWe = net dependable electric generating capacity in megawatts;

$\underline{P}$ = a vector of factor input prices such as wage rates, prices of equipment, prices of materials, etc.;

$\underline{Z}$ = a vector of "state-of-nature" (exogeneous) variables.

The cost reports for constructing electric powerplants are mixed current dollars which are spent over the period from the date the construction starts to the commercial operation date. Furthermore, the input prices change over the duration of construction and hence they are not included as the appropriate explanatory arguments of the plant cost function. The total capital costs in constant dollars are used as the dependent variable in estimating the plant cost function.

The explanatory variables included are: (i) plant capacity size (MWe) to capture the economies of scale, (ii) the construction start year (START) to explain intertemporal changes due to exogeneous factors such as regulation impacts, technological changes, productivity changes, etc.; and finally (iii) a regional dummy variable (SOUTH) to capture regional cost differences. (Note: log of START was used in the LWR cost equation.)

The statistical capital cost function is specified as follows:

$$\text{Log } C^{*} = b_o + b_1 \text{ Log MWe} + b_2 \text{ START} + b_3 \text{ SOUTH} \qquad \text{(A16)}$$

where C^{*} = total plant costs in constant dollars.

SOUTH = 1 for South and zero for non-South.

C. Empirical Results

The cost data come from two sources: the U. S. Department of Labor-Construction Labor Demand System's Electric Utility Surveys conducted in 1978 through 1981, and Steam-Electric Plant Construction Costs and Annual Production Expenses, U. S. Department of Energy, Energy Information Administration, Federal Power Commission, 1960-1975. The U.S. DOL-CLDS's Annual Electric Utility Surveys (1978-1981) are also the basis of the construction labor requirements data. (See Appendix E for detailed data sources).

Since the reported capital costs for constructing electric powerplants are the mixed current dollars spent over the period from the date of beginning cash flow to construction ending date, they are converted into 1980 dollars by utilizing a cash flow model with use of the Handy-Whitman Index of Public Utility Construction Costs.

The estimated construction labor requirement and cost functions are shown in Tables A5 and A 6, respectively.

IV. Craft Conversion Profiles

The craft profiles convert the planned and forecasted electric powerplant projects into time-phased construction labor requirements by craft. These profiles have been developed by the U. S. Department of Labor/Construction Labor Demand System staff with assistance from Contractor Mutual Association (CMA), Tennessee Valley Authority (TVA), and many utility companies which provided field data. CLDS continues to conduct the major powerplant project survey for updating project data and conversion profiles.

The electric powerplant projects are classified into three categories at the two digit level and 12 subcategories at the three digit level. Table A7 shows the categorization for the 18 unique craft conversion profiles for electric powerplant projects. The craft profiles have a matrix form of 15 crafts by 25 time periods. Matrix A is defined as:

$$A = (a_{ij}) , \quad i = 15, \quad j = 25$$

where a_{ij} = a proportion of the i-th craft requirements in the j-th period. The actual months of construction are allocated to the 25 time periods.

Table A 5

Estimated Regression Equations of Labor Requirements Functions for Electric Powerplants

Type	Estimated Equation[a]	R^2	F	N
LWR	Log WH = -0.8841 + 0.7560.Log C (-0.4) (4.8)	0.55	22.8	21
Coal-Fired	Log WH = -3.0886 + 0.8899 Log C (-2.7) (10.1)	0.68	101.1	50
Hydro-Dam	$WH = 3495.2505\ (MWe/200)^{1.1312}$	0.89		15
Pump-Storage	WH = 1014.274 + 5.523 MWe	0.62		6

Note: a WH = thousands of work-hours
C = construction costs in thousands of 1980 dollars
MWe = net dependable capacity in megawatts
t - statistics in parenthesis.

Table A 6

Estimated Regression Equations of Capital Cost Functions for Electric Powerplants

Type	Estimated Equations [a]	R^2	F	N
L W R	Log CC = 1.6515 + 0.6278 Log MWe + 0.5861 Log T-0.1411.S	0.70	78.4	104
	(1.7) (4.2) (9.7) (-2.3)			
Coal-fired	Log C = 2.9483 + 0.9233 Log Mwe + 0.05189.YR - 0.1652.S	0.74	64.0	71
	(2.3) (13.8) (3.6) (-2.5)			
Hydro-Dam	Log C = 8.4830 + 0.6860 Log MWe	0.53		14
	(8.4) (3.7)			
Pump-Storage	Log C = 7.5421 + 0.7741 Log MWe	0.88		6
	(7.4) (5.4)			

Note: a. CC = construction costs in millions of 1980 dollars t - statistics in parenthesis.
C = construction costs in thousands of 1980 dollars
S = 1 for south region (U. S. DOL Regions IV and VI), 0 for other regions
MWe = net dependable capacity in megawatts
T = 1 for 1966 of construction start, 2 for 1967 of construction start, ...
YR = year of construction start

Table A 7
Construction Profile Types
for Electric Powerplants

Construction Classification	Construction Type	Nominal Size	Profile Craft Phase	Source
1. Electric Powerplants				
11. Nuclear				
111. Boiling Water Reactor (BWR)	1111. South after 1981	900 MWe, 1200 MWe	20 X 25	CMA - TVA - ClDS
	1112. Nonsouth after 1981	900 MWe, 1200 MWe	20 X 25	CMA - TVA - CLDS
112. Pressurized Water Reactor (PWR)	1121. South	900 MWe, 1200 MWe	20 X 25	CMA - TVA - CLDS
	1122. Nonsouth	900 MWe, 1200 MWe	20 X 25	CMA - TVA - CLDS
113. High Temperature Gas Reactor (HTGR)	1131. HTGR	1500 MWe	20 X 25	ESPM75-CLDS
114. Others	1141. Others	1100 MWe	20 X 25	CMA - TVA - CLDS
12. Fossil Fired				
121. Coal-fired	1211. South	300 MWe, 600 MWe	18 X 25	CMA - TVA - CLDS
	1212. Nonsouth-Large	600 MWe	18 X 25	CMA - TVA - CLDS
	1213. Nonsouth-Small	300 MWe	18 X 25	CMA - TVA - CLDS
122. Oil-fired	1221. South	300 MWe, 600 MWe	18 X 25	CMA - Tva - Clds
	1222. Nonsouth-Large	600 MWe	18 X 25	CMA - TVA - CLDS
	1223. Nonsouth-Small	300 MWe	18 X 25	CMA - TVA - CLDS
123. Gas-fired	1231. Gas-fired	300 MWe, 500 MWe	18 X 25	CMA - Tva - CLDS
124. Conversion	1241. Conversion	250 MWe	11 X 1	ESPM75-CLDS
13. Hydroelectric				
131. Concrete Dam	1311. Concrete Dam	200 MWe	14 X 25	TVA - CLDS
132. Earth Dam	1321. Earth Dam	200 MWe	14 X 25	TVA - CLDS
133. Generating Unit Addition	1331. Unit Addition	50 MWe	15 X 10	TVA - CLDS
134. Pumped Storage	1341. Pumped Storage	800 MWe	14 X 25	TVA - CLDS

Table B1

Electric Capacity Additions[a] in Region I
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	-	-	-	1200 (1)	1200 (1)	1156 (1)	-	-	-	-	-	-	-	-	-	-
Coal-fired	863 (1)	-	-	-	-	-	-	568 (1)	-	-	190 (1)	190 (1)	190 (1)	190 (1)	190 (1)	190 (1)
Oil-fired	-	628 (3)	176 (2)	3 (1)	708 (3)	3 (1)	-	75 (1)	3 (1)	-	-	-	-	-	-	-
Gas-fired	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	-	28 (3)	-	-	-	-	-	83 (1)	-	-	-	-	-	-	-	-
Pump-Storage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Region I	863 (1)	656 (6)	176 (2)	1203 (2)	1908 (4)	1159 (2)	-	726 (3)	3 (1)	-	190 (1)	190 (1)	190 (1)	190 (1)	190 (1)	190 (1)

Note: a Both Planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's Inventory of Powerplants in the United States (1981), while LWR projects were obtained from U. S. NRC's Nuclear Powerplants Construction Status Report (April 1981). Forecasted projects based on U. S. DOE/EIA's 1981 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13.

Table B 2

Electric Capacity Additions[a] in Region II
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	1115 (1)	-	819 (1)	-	-	-	2167 (2)	-	-	1067 (1)	-	-	-	-	-	-
Coal-fired	-	-	-	-	650 (1)	-	-	300 (1)	290 (1)	1652 (2)	1320 (2)	1370 (2)	520 (1)	810 (2)	520 (1)	520 (1)
Oil-fired	-	-	60 (1)	180 (3)	-	-	-	-	-	-	-	-	-	-	-	130 (2)
Gas-fired	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	-	-	32 (4)	10 (1)	13 (1)	2 (1)	8 (1)	92 (4)	16 (1)	-	2 (1)	-	-	-	-	-
Pump-Storage	-	-	-	-	-	-	-	1000 (1)	900 (1)	900 (1)	-	-	-	-	-	-
Region	1115 (1)	-	911 (6)	190 (4)	663 (2)	2 (1)	2175 (3)	1392 (6)	1206 (3)	3619 (4)	1322 (3)	1370 (2)	520 (1)	810 (2)	520 (1)	650 (3)

Note: a Both Planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's Inventory of Powerplants in the United States (1981), while LWR projects were obtained from U. S. NRC's Nuclear Powerplants Construction Status Report (April 1981). Forecasted projects based on U. S. DOE/EIA's 1981 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13.

Table B 3

Electric Capacity Additions[a] in Region III
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	907 (1)	1050 (1)	1050 (1)	1055 (1)	-	833 (1)	1055 (1)	-	-	907 (1)	-	-	-	-	-	
Coal-fired	684 (1)	-	685 (1)	-	-	-	684 (1)	-	1030 (2)	1317 (2)	1970 (4)	2370 (4)	940 (2)	940 (2)	940 (2)	940 (2)
Oil-fired	-	659 (1)	-	-	-	785 (2)	150 (6)	-	-	-	664 (1)	664 (1)	664 (1)	664 (1)	664 (1)	663 (1)
Gas-fired	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	-	7 (1)	-	30 (1)	-	188 (1)	-	-	-	-	-	-	-	-	-	-
Pump-Storage	-	-	-	-	-	1050 (1)	1550 (3)	500 (2)	-	-	-	-	-	-	-	-
Region III	1591 (2)	1716 (3)	1735 (2)	1085 (2)	-	2856 (5)	3439 (11)	500 (2)	1030 (2)	2224 (3)	2634 (5)	3034 (5)	1604 (3)	1604 (3)	1604 (3)	1604 (3)

Note: a Both planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's <u>Inventory of Powerplants in the United States</u> (1981), while LWR projects were obtained from U. S. NRC's <u>Nuclear Powerplants Construction Status Report</u> (April 1981). Forecasted projects based on U. S. DOE/EIA's <u>1981 Annual Report to Congress,</u> February 1982, DOE/EIA-0173(81)13.

Table B 4

Electric Capacity Additions[a] in Region IV
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	1969 (2)	5655 (5)	3167 (3)	1145 (1)	3223 (3)	3608 (3)	-	2010 (2)	-	1280 (1)	-	1280 (1)	-	-	-	-
Coal-fired	235 (1)	4165 (8)	670 (1)	1377 (2)	2567 (4)	4324 (8)	615 (2)	3381 (5)	7283 (10)	6040 (9)	3630 (6)	6248 (9)	3295 (5)	3403 (5)	2620 (4)	2620 (4)
Oil-fired	446 (1)	2126 (3)	116 (2)	88 (1)	138 (2)	315 (4)	200 (1)	115 (2)	-	-	-	-	750 (1)	-	-	-
Gas-fired	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	112 (1)	-	-	424 (6)	300 (1)	100 (1)	-	-	70 (1)	-	-	-	-	-	-	-
Pump-Storage	863 (1)	-	-	-	-	-	1300 (5)	675 (1)	-	-	-	-	-	-	-	-
Region IV	3625 (6)	11946 (16)	3953 (6)	3034 (10)	6228 (10)	8347 (16)	2115 (8)	6181 (10)	7353 (11)	7320 (10)	3630 (6)	7528 (10)	4045 (6)	3403 (5)	2620 (4)	2620 (4)

Note: a Both Planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's Inventory of Powerplants in the United States (1981), while LWR projects were obtained from U. S. NRC's Nuclear Powerplants Construction Status Report (April 1981). Forecasted projects based on U. S. DOE/EIA's 1981 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13.

Table B 5

Electric Capacity Additions[a] in Region V
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	-	1888 (2)	2171 (2)	4529 (5)	1120 (1)	1120 (1)	2250 (2)	2335 (2)	933 (1)	-	-	-	-	1120 (1)	1120 (1)	-
Coal-fired	1942 (3)	1580 (3)	2363 (7)	1128 (5)	3387 (4)	3351 (6)	790 (2)	3959 (9)	2460 (9)	2770 (5)	2064 (5)	2470 (4)	4070 (7)	3470 (6)	3470 (6)	3470 (6)
Oil-fired	7 (1)	4 (1)	6 (1)	30 (1)	240 (1)	-	-	-	-	190 (3)	-	-	-	-	-	-
Gas-fired	-	6 (1)	6 (1)	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	-	48 (1)	-	-	-	96 (1)	-	-	30 (1)	-	-	-	-	-	-	-
Pump-Storage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Region V	1949 (4)	3526 (8)	4546 (11)	5687 (11)	4747 (6)	4567 (8)	3040 (4)	6294 (11)	3423 (11)	2960 (8)	2064 (5)	2470 (4)	4070 (7)	4590 (7)	4590 (7)	3470 (6)

Note: a Both Planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's Inventory of Powerplants in the United States (1981), while LWR projects were obtained from U. S. NRC's Nuclear Powerplants Construction Status Report (April 1981). Forecasted projects based on U. S. DOE/EIA's 1981 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13.

Table B 6

Electric Capacity Additions[a] in Region VI
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	-	1111 (1)	2224 (2)	2184 (2)	-	1250 (1)	-	-	-	-	1150 (1)	1150 (1)	1150 (1)	-	-	-
Coal-fired	1176 (2)	3437 (6)	3623 (7)	2425 (4)	850 (2)	5370 (8)	4790 (7)	3326 (5)	5598 (10)	2840 (3)	6016 (10)	4390 (7)	5140 (9)	4640 (8)	4640 (8)	4640 (8)
Oil-fired	532 (3)	90 (1)	180 (2)	-	-	-	-	-	-	-	-	-	-	-	-	-
Gas-fired	-	-	67 (1)	-	50 (1)	-	-	500 (1)	-	-	-	-	-	-	-	-
Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pump-Storage	-	-	-	-	-	-	-	-	-	-	60 (1)	60 (1)	60 (1)	60 (1)	60 (1)	60 (1)
Region VI	1708 (5)	4638 (8)	6094 (12)	4609 (6)	900 (3)	6620 (9)	4790 (7)	3826 (6)	5598 (10)	2840 (6)	7226 (12)	5600 (9)	6350 (11)	4700 (9)	4700 (9)	4700 (9)

Note: a Both planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's Inventory of Powerplants in the United States (1981), while LWR projects were obtained from U. S. NRC's Nuclear Powerplants Construction Status Report (April 1981). Forecasted projects based on U. S. DOE/EIA's 1981 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13.

Table B 7

Electric Capacity Additions[a] in Region VII
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	-	-	1120 (1)	1150 (1)	-	-	-	-	-	-	-	-	-	-	-	-
Coal-fired	508 (1)	2046 (8)	1130 (3)	1705 (3)	-	1350 (3)	720 (1)	650 (1)	100 (1)	729 (1)	245 (2)	188 (1)	188 (1)	188 (1)	188 (1)	188 (1)
Oil-fired	-	290 (4)	95 (2)	275 (3)	-	52 (2)	90 (1)	-	120 (2)	-	-	-	-	-	-	-
Gas-fired	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	-	-	31 (1)	27 (1)	-	-	-	-	-	-	-	-	-	-	-	-
Pump-Storage	-	54 (2)	-	-	-	108 (4)	-	-	-	-	268 (1)	268 (1)	268 (1)	268 (1)	268 (1)	268 (1)
Region VII	508 (1)	2390 (14)	2376 (7)	3157 (8)	-	1510 (9)	810 (2)	650 (1)	220 (3)	729 (1)	513 (3)	456 (2)	456 (2)	456 (2)	456 (2)	456 (2)

Note: a Both planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's Inventory of Powerplants in the United States (1981), while LWR projects were obtained from U. S. NRC's Nuclear Powerplants Construction Status Report (April 1981). Forecasted projects based on U. S. DOE/EIA's 1931 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13.

Table B 8

Electric Capacity Additions[a] in Region VIII
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coal-fired	1100 (3)	1652 (4)	550 (1)	3394 (8)	4667 (7)	1515 (4)	595 (2)	1220 (2)	2021 (4)	750 (1)	2618 (4)	1398 (2)	1398 (2)	1398 (2)	1398 (2)	1398 (2)
Oil-fired	-	-	-	-	-	-	-	-	-	-	16 (1)	-	-	16 (1)	-	-
Gas-fired	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	-	-	-	144 (4)	-	420 (4)	76 (1)	-	-	-	-	-	-	-	-	-
Pump-Storage	-	200 (2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Region VIII	1100 (3)	1852 (6)	550 (1)	3538 (12)	4667 (7)	1935 (8)	671 (3)	1220 (2)	2021 (4)	750 (1)	2634 (5)	1414 (3)	1414 (3)	1414 (3)	1414 (3)	1414 (3)

Note: a Both Planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's _Inventory of Powerplants in the United States_ (1981), while LWR projects were obtained from U. S. NRC's _Nuclear Powerplants Construction Status Report_ (April 1981). Forecasted projects based on U. S. DOE/EIA's _1981 Annual Report to Congress_, February 1982, DOE/EIA-0173(81)13.

Table B 9

Electric Capacity Additions[a] in Region IX
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	-	4560 (4)	2370 (2)	-	-	1270 (1)	-	-	-	-	-	-	-	-	-	-
Coal-fired	350 (1)	650 (2)	-	500 (2)	580 (3)	1775 (4)	1600 (2)	2325 (4)	-	1015 (2)	788 (2)	1292 (3)	338 (1)	838 (2)	338 (1)	338 (1)
Oil-fired	170 (4)	185 (2)	605 (4)	189 (5)	-	407 (6)	1029 (10)	562 (10)	91 (2)	-	21 (1)	-	-	-	-	70 (1)
Gas-fired	70 (1)	70 (1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	56 (4)	214 (10)	22 (5)	452 (5)	24 (3)	19 (1)	373 (4)	2 (1)	3 (1)	1 (1)	-	-	-	-	-	-
Pump-Storage	-	-	1367 (2)	-	-	-	200 (1)	-		-	-	-	-	-	-	-
Region IX	646 (10)	5694 (19)	4364 (13)	1141 (12)	604 (6)	3471 (12)	3202 (17)	2889 (15)	94 (3)	1016 (3)	809 (3)	1292 (3)	338 (1)	838 (2)	338 (1)	408 (2)

Note: a Both Planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's *Inventory of Powerplants in the United States* (1981), while LWR projects were obtained from U. S. NRC's *Nuclear Powerplants Construction Status Report* (April 1981). Forecasted projects based on U. S. DOE/EIA's *1981 Annual Report to Congress,* February 1982, DOE/EIA-0173(81)13.

Table B 10

Electric Capacity Additions[a] in Region X
by Type, 1980-1995
(Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	-	-	1100 (1)	-	1218 (1)	2458 (2)	1240 (1)	-	-	-	2537 (2)	-	2507 (2)	-	-	-
Coal-fired	530 (1)	-	-	-	-	-	115 (1)	-	115 (1)	-	470 (1)	470 (1)	470 (1)	470 (1)	470 (1)	470 (1)
Oil-fired	-	356 (4)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gas-fired	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	1033 (4)	566 (7)	342 (5)	-	22 (1)	160 (2)	-	-	-	-	-	-	-	-	-	-
Pump-Storage	108 (2)	162 (3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Region X	1671 (7)	1084 (14)	1442 (6)	-	1240 (2)	2618 (4)	1355 (2)	-	115 (1)		3007 (3)	470 (1)	2977 (3)	470 (1)	470 (1)	470 (1)

Note: a Both Planned and forecasted projects are included. Planned projects were obtained from U. S. DOE/EIA's Inventory of Powerplants in the United States (1981), while LWR projects were obtained from U. S. NRC's Nuclear Powerplants Construction Status Report (April 1981). Forecasted projects based on U. S. DOE/EIA's 1981 Annual Report to Congress, February 1982, DOE/EIA-0173(81)13.

Table C 1

Electric Generating Capacity Additions[a] in the United States by Fuel-Type, 1980-1995 (Megawatts)

Type	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
LWR	3991 (4)	14264 (13)	14021 (13)	11203 (11)	6761 (6)	11695 (10)	6712 (16)	5578 (15)	-	2347 (2)	-	2180 (2)	2570 (2)	2133 (2)	1233 (1)	3699 (3)
Coal-fired	7388 (14)	10463 (24)	8915 (19)	7084 (14)	7458 (12)	12431 (21)	7077 (11)	6778 (11)	4550 (6)	5246 (8)	3145 (4)	1310 (2)	750 (1)	750 (1)	-	-
Oil-fired	991 (4)	960 (3)	830 (3)	-	620 (1)	-	-	-	620 (1)	-	-	-	-	-	-	-
Gas-fired	-	-	70 (1)	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydro	632 (8)	328 (8)	572 (9)	1018 (11)	784 (7)	482 (6)	228 (4)	-	67 (1)	88 (4)	-	-	-	-	-	-
Pump-Storage	917 (2)	-	1050 (1)	-	-	1050 (1)	1550 (3)	2175 (4)	-	-	-	-	-	-	-	-
Total	13919 (32)	26015 (48)	25458 (46)	19365 (36)	15623 (26)	25658 (38)	15567 (24)	14531 (20)	5237 (8)	7681 (14)	3145 (4)	3490 (4)	3320 (3)	2883 (3)	1233 (1)	3699 (3)

Note: a Planned project data were obtained from Electrical World, Vol. 193, No. 1 January 1981.

Table C 2

On-Site Manual Construction Labor Requirements for Electric Powerplants
in United States, 1980-1990
(Thousands of Work-Hours)

(based on project data obtained from Electrical World 1981 Electric Utility Survey)

Craft	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Total
Asbestos Wks/Insul	5092	5528	5058	4485	4669	3325	2209	1619	1344	983	479	34791
Boilermakers	16984	15289	13121	14021	14057	9837	7174	6307	5330	2196	1084	105399
Bricklayers-Stonemason	894	708	608	484	447	282	251	203	160	51	40	4128
Carpenters	26407	21264	16952	14171	11566	8266	5834	4253	2654	1567	990	113924
Cement-Conc. Finishers	3383	2898	2394	2011	1659	1253	881	608	384	246	156	15873
Electricians	39382	37351	30491	24622	21622	15689	10788	7915	6550	4463	2139	201022
Iron Workers	20627	16768	13836	11879	9903	7071	5102	4087	2669	1412	893	94247
Laborers	39052	33831	27796	21971	18731	13412	8993	6599	4666	2756	1511	179318
Millwrights	6853	6631	5700	4996	4691	3676	2413	1591	1275	861	398	39085
Operating Engineers	19595	17045	13947	11572	9702	7113	5209	3738	2601	1326	801	92649
Painters	5543	5497	5016	3930	3652	2750	1644	1124	967	688	355	31166
Pipefitters	61136	57923	46542	37285	32450	22487	15136	11279	9859	6396	3010	303503
Sheet Metal Workers	4254	4355	3604	2842	2719	2119	1385	1133	936	818	309	24474
Truck Drivers	10028	8676	7075	5858	4836	3475	2558	1985	1446	842	501	47280
Other Workers	1190	997	937	942	909	747	433	223	139	84	55	6656
Total Workers	260419	234760	193076	161066	141619	101501	70009	52665	40980	24691	12720	1293515

Table C 2 (continued)

(Percent Change)

Craft	80-82	82-84	84-86	86-88	88-90	80-Peak	Peak Year
Asbestos Wks/Insul	-.7	-7.7	-52.7	-39.2	-64.4	8.6	1981
Boilermakers	-22.7	7.1	-49.0	-25.7	-79.7	-	1980
Bricklayers-Stonemason	-32.0	-26.5	-43.8	-28.0	-74.9	-	1980
Carpenters	-35.8	-31.8	-49.6	-54.5	-62.7	-	1980
Cement-Conc. Finishers	-29.2	-30.7	-49.6	-56.4	-59.4	-	1980
Electricians	-22.6	-29.1	-50.1	-39.3	-67.3	-	1980
Iron Workers	-32.9	-28.4	-48.5	-47.7	-66.5	-	1980
Laborers	-28.8	-32.6	-52.0	-48.1	-67.6	-	1980
Millwrights	-16.8	-17.7	-48.6	-47.2	-68.8	-	1980
Operating Engineers	-28.8	-30.4	-46.3	-50.1	-69.2	-	1980
Painters	-9.5	-27.2	-55.0	-41.2	-63.3	-	1980
Pipefitters	-23.9	-30.3	-53.4	-34.9	-69.5	-	1980
Sheet Metal Workers	-15.3	-24.6	-49.1	-32.4	-67.0	2.4	1981
Truck Drivers	-29.4	-31.6	-47.1	-43.5	-65.4	-	1980
Other Workers	-21.3	-3.0	-52.4	-67.9	-60.4	-	1980
Total Workers	-25.9	-26.7	-50.6	-41.5	-69.0	-	1980

Appendix D: Method for Converting Capital Costs from 1980 Dollars to Current Dollars

This appendix explains a step-by-step method for computing the capital costs in current or accounting dollars from constant dollars (1980 dollars) for LWR and coal-fired powerplants. Table D1 shows an example for a LWR powerplant with net dependable capacity of 1200 MWe, located in a non-South region, which starts construction in 1983 and plans to generate power in 1992, with the nuclear steam supply system ordered in 1981. An example for a coal-fired powerplant is shown in Table D2. It is assumed that: (1) the installed capacity is 600 MWe with a scrubber; (2) it is located in a non-South region; (3) the steam supply system is ordered in 1981; (4) its construction starts in 1982; and (5) the commercial operation year is 1986.

Step 1: Cash Flow Percents of Costs in Current Dollars

The annual cash flow percents of capital costs in current dollars are estimated for a particular powerplant under consideration by utilizing the following cash flow equations (See Figure D1 for cash flow of a LWR plant):

$$Y = \left\{ 1 - \left[\cos\ (\pi X/2) \right]^{2.21} \right\}^{2.42} \quad \text{for LWR} \qquad \text{(D1)}$$

$$Y = \left\{ 1 - \left[\cos\ (\pi X/2) \right]^{2.31} \right\}^{2.61} \quad \text{for coal-fired} \qquad \text{(D2)}$$

where Y = fraction of cumulative costs (cash flow);

X = fraction of total period, which is measured from the date of steam supply system order to the date of commercial operation, $0 \leq X \leq 1$.

Annual cash flow percent F_t for each year is calculated from equations (D1) or (D2) as follow:

$$F_t = Y_t - Y_{t-1} \qquad \text{(D3)}$$

where t is the year under consideration. Column (1) of Tables D1 and D2 shows annual cash flow for LWR and coal-fired powerplants, respectively.

Table D 1

Example[a] of Converting Capital Costs from 1980 Dollars to Current Dollars for a LWR Powerplant

Year	(1) Cash Flow (%)	(2) H-W Index Deflator	(3) =(1)x(2)	(4) =(3)/(3)* Distribution (%)	(5) =(4)x(5)* Millions of 1980 Dollars	(6) H-W Index Multiplier	(7) =(5)x(6) Millions of Current Dollars
1981	0.01	215.2/235.1	0.01	0.02	0.5	235.1/215.2	0.5
1982	0.17	215.2/256.9	0.14	0.29	7.0	256.9/215.2	8.4
1983	1.02	215.2/280.6	0.78	1.58	37.9	280.6/215.2	49.4
1984	3.09	215.2/306.6	2.17	4.37	104.8	306.6/215.2	149.3
1985	6.63	215.2/335.0	4.26	8.58	205.8	335.0/215.2	320.4
1986	11.10	215.2/365.9	6.53	13.15	315.5	365.9/215.2	536.4
1987	15.39	215.2/399.8	8.28	16.67	399.9	399.8/215.2	742.9
1988	18.06	215.2/436.8	8.90	17.91	429.7	436.8/215.2	872.2
1989	17.98	215.2/477.2	8.11	16.33	391.7	477.2/215.2	868.6
1990	14.78	215.2/521.3	6.10	12.29	294.8	521.3/215/2	714.1
1991	9.10	215.2/568.2	3.45	6.94	166.5	568.2/215.2	439.6
1992	2.67	215.2/619.3	0.93	1.87	44.9	619.3/215.2	129.2
	100.00		49.66 (3)*	100.00	2399.0 (5)*		4831.0

NOTE: a. This example is for a LWR power plant: capacity = 1200 MWe, location = non-South, year of nuclear steam supply system purchase = 1981 year of construction start = 1983, year of commercial operation = 1992,

(1). Cash Flow of construction costs in current dollars estimated from equation (D1).
(2)(6). Handy-Whitman Index, 1972=100.00.
(4). Distribution of construction costs in 1980 dollars.
(5)*. Total construction costs in 1980 dollars, 1200 (MWe) x 1999 ($80/MWe) = $ 2399 x 10^6 ($80).

Table D 2

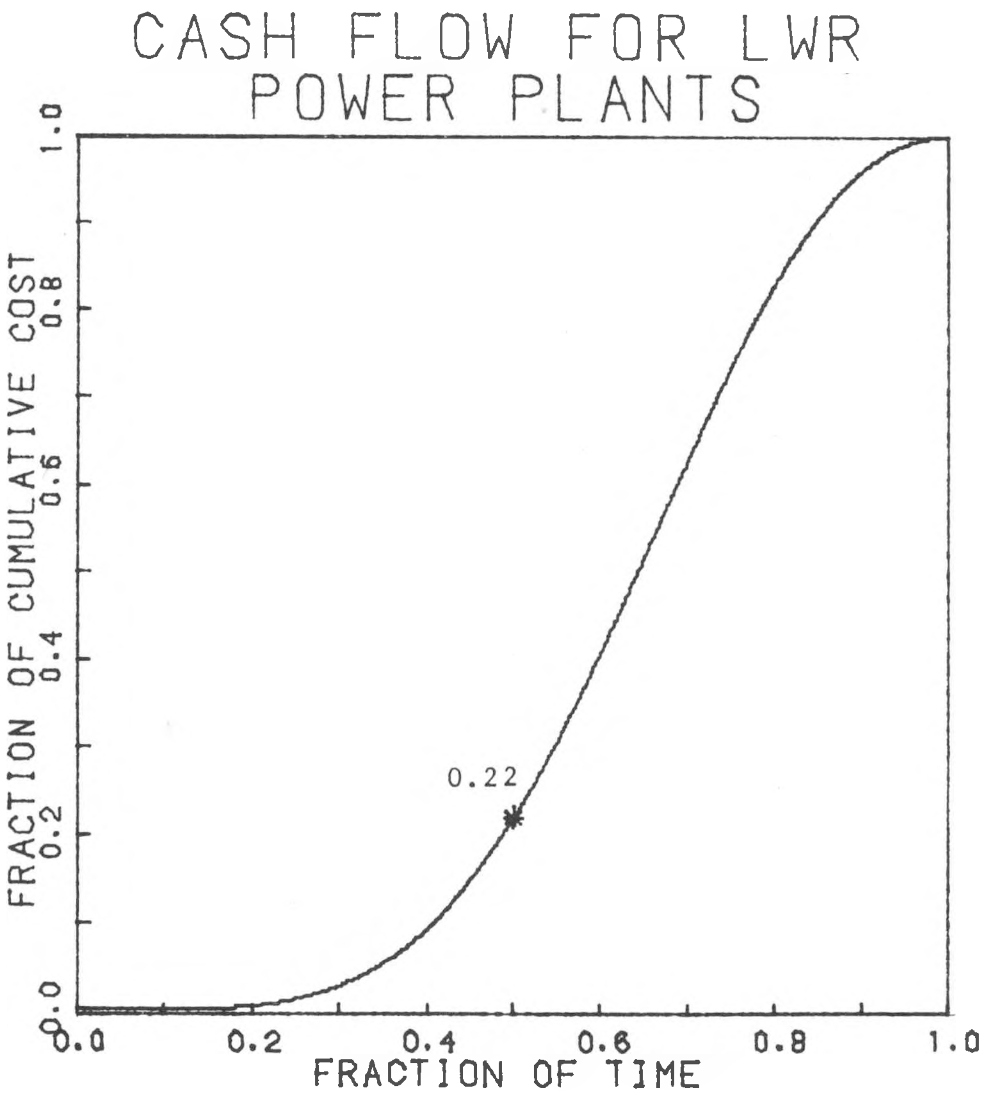
Example[a] of Converting Capital Costs from 1980 Dollars to Current Dollars for a Coal-Fired Powerplant

	Year	(1) Cash Flow (%)	(2) H-W Index Deflators	(3) =(1)x(2)	(4) =(3)/(3)* Distribution (%)	(5) =(4)x(5)* Millions of 1980 Dollars	(6) H-W Index Multiplier	(7) =(5)x(6) Millions of Current Dollars
1	1981	0.12	215.2/235.1	0.11	0.16	0.9	235.1/215.2	1.0
2	1982	3.58	215.2/256.9	3.00	4.37	25.5	256.9/215.2	30.4
3	1983	17.40	215.2/280.6	13.34	19.45	113.3	280.6/215.2	147.7
4	1984	34.45	215.2/306.6	24.18	35.26	205.4	306.6/215.2	292.6
5	1985	33.36	215.2/335.0	21.43	31.25	182.1	335.0/215.2	283.5
6	1986	11.09	215.2/365.9	6.52	9.51	55.4	365.9/215.2	94.5
		100.00		68.58 (3)*	100.00	582.6 (5)*		849.4

NOTE: a. This example is for a coal-fired power plant: Capacity = 600 MWe, location = non-South, Year of steam supply purchase = 1981, year of construction start = 1982, year of commercial operation = 1986.

(1). Cash flow of construction cost in current dollars estimated from equation D2.
(2).(6). Handy-Whitman Index, 1972 = 100.00.
(4). Distribution of construction cost in 1980 dollars.
(5)*. Total construction cost in 1980 dollars, 600 (MWe) x 971 ($80/KWe) = 582.6 x 10^6 ($80).

Figure D1


CASH FLOW FOR LWR
POWER PLANTS
FRACTION OF CUMULATIVE COST
0.0
0.2
0.4
0.6
0.8
1.0
0.22
0.0
0.2
0.4
0.6
0.8
1.0
FRACTION OF TIME

Step 2: Distribution Percents of Costs in 1980 Dollars

The annual distribution percents of costs in 1980 dollars vary for individual powerplant projects, because construction duration, calendar years of total period, and the applicable Handy-Whitman indices make the distribution pattern different. The Handy-Whitman deflators for 1980 dollars are utilized in estimating annual distribution percent D_t for each year:

$$D_t = \left[F_t \cdot (HWI_{to} / HWI_t) \right] / FI \qquad \text{(D4)}$$

where HWI_{to} is the Handy-Whitman index in the base year (t_o = 1980) and HWI_t the Handy-Whitman index in the year t, and FI is:

$$FI = \sum_{t=t_1}^{t_m} F_t \cdot (HWI_{t_o} / HWI_t) \qquad \text{(D5)}$$

where t_1 is the year of steam supply system order and t_m the year commercial operation is reached. The annual distribution percents calculated for LWR and coal-fired plants are shown in column (4) in Tables D1 and D2.

Step 3: Cost Distribution in 1980 Dollars

Total capital cost of a specific powerplant project is estimated from the following regression equations for LWR and coal units:

$$\text{(LWR)}\ \text{Log CC} = \underset{(1.7)}{1.6515} + \underset{(4.2)}{0.6278}\ \text{Log MWe} + \underset{(9.7)}{0.05861}\ \text{Log T} \underset{(-2.3)}{-0.1411}\ \text{S} \qquad \text{(D6)}$$

$$R^2 = 0.70\ ,\quad F = 78.4\ ,\quad N = 104\ ,\quad \text{(t values)}$$

$$\text{(Coal-fired)} \quad \text{Log } C = \underset{(2.3)}{2.9483} + \underset{(13.8)}{0.9233} \text{ Log MWe} + \underset{(3.6)}{0.05189} \text{ YR} \qquad \text{(D7)}$$

$$\underset{(-2.5)}{-0.1652} \text{ S}$$

$$R^2 = 0.74, \quad F = 64.0, \quad N = 71, \text{ (t values)}$$

where CC = total capital costs in millions of 1980 dollars,

C = total capital costs in thousands of 1980 dollars,

MWe = capacity in megawatts of electricity,

T = 1 for 1966 construction start, 2 for 1967 construction start, etc.,

YR = year of construction start, 72, 73, etc.,

S = 1 for South region (U.S. DOL Regions IV and VI),

0 for other regions.

For estimating total capital costs of a coal-fired powerplant with scrubber, a 20 percent increment is added to total costs calculated from the above equation. For the present forecast, it is assumed that for the LWR and coal-fired powerplants, capital costs increase at a decreasing rate after 1978 and 1980, respectively, and stabilize in 1990. The estimated costs in 1980 dollars are distributed over the years of the period under consideration by:

$$COST_t = D_t \cdot TC \qquad \text{(D8)}$$

where $COST_t$ is annual cost (in 1980 dollars) for year t and TC is total capital costs (in 1980 dollars) estimated from the regression equations described above. Column (5) in Tables D1 and D2 shows $COST_t$ for our examples.

Step 4: Capital Costs in Current Dollars

The Handy-Whitman multipliers are utilized in converting costs from 1980 dollars to current dollars as follows:

$$CCOST_t = COST_t \cdot (HWI_t/WHI_{t_o}) \tag{D9}$$

where $CCOST_t$ represents annual costs in current dollars adjusted by the Handy-Whitman multiplier, (HWI_t/HWI_{t_o}). Hence, total capital costs (TCC) in current dollars for a specific powerplant project under consideration are calculated as a sum of annual adjusted costs over the period:

$$TCC = \sum_{t=t_1}^{t_m} CCOST_t \tag{D10}$$

Total cost in current dollars for our examples are shown in the last column (7) in Tables D1 and D2.

Appendix E: Data Sources and References

Subjects	Data Sources
Labor Requirements	Annual Electric Utility Surveys, 1978-1981, by U. S. Department of Labor, Construction Labor Demand System.
Plant Costs	Annual Electric Utility Surveys, 1978-1981, by U. S. Department of Labor, Construction Labor Demand System.
	Steam-Electric Plant Construction Costs and Annual Production Expenses, U. S. Department of Energy, Energy Information Administration (old FPC), Washington, D.C., 1960-1978.
	Central Station Nuclear Plants, U. S. ERDA, Washington, D.C., March 31, 1976.
	The Nuclear Industry, U. S. AEC, Washington, D.C., 1974.
	Handy-Whitman Index of Public Utility Construction Costs, Whitman, Requardt and Associates, Baltimore, MD., 1960-1981.
	User's Instructions for Preliminary Version of the CONCEPT-5 Computer Code, ORNL/TM-6230 by C. R. Hudson II, Oak Ridge National Laboratory, Oak Ridge, TN. February 1978.
Projects	Inventory of Power Plants in the U.S., U. S. Department of Energy, Energy Information Administration, Washington, D.C., 1981.
	U. S. Central Station Nuclear Electric Generating Units: Significant Milestones, U. S. Department of Energy, Office of Nuclear Reactor Programs, Washington, D.C., March 1981.
	Nuclear Power Plants Construction Status Report, U. S. Nuclear Regulatory Commission, NUREG - 0030, Vol. 4, Washington, D.C. April 1981.
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