EMPLOYMENT AND LAND-USE IMPACTS
OF RESOURCE PROGRAM ELEMENTS

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SUMMARY

The Pacific Northwest Laboratory (PNL) evaluated several power resource alternatives under consideration by the Bonneville Power Administration in its Resource Program Environmental Impact Statement (RPEIS). The purpose of this evaluation was to determine the potential impacts of each alternative in terms of land use and employment.

We reviewed the literature that describes land-use and employment impacts to derive estimates of each type of effect. These estimates were scaled to a per-megawatt basis for use as multipliers in the RPEIS analysis. Multipliers for employment were taken from the literature and developed from power plant capital cost estimates. Land-use multipliers were taken from the literature or estimated from existing plants. In this report we compared information sources and estimates to develop the most applicable multipliers.

Table S.1 shows employment levels required (in terms of employee years per MW of plant capacity) for the construction and operation phases of each energy-generating resource alternative analyzed. Table S.2 shows the amounts of land required (in terms of acres per MW capacity) for the construction and operation phases of each energy-generating resource alternative analyzed.

TABLE S.1. Employment Impacts Summary

Resource	Construction Employment (employee years per MW capacity)	Operations Employment (employees per MW capacity)
Pulverized coal	4.7	0.5
Atmospheric fluidized bed coal	5.1	0.7
Coal gasification	5.7	0.9
Cogeneration (overall average)	15.1	4.5
Cogeneration (wood-fired)	9.6	4.5 ^(a)
Cogeneration (municipal solid waste)	24.1	4.5
Combined cycle combustion turbine	1.4	0.1
Geothermal	4.1	0.3
Hydroelectric (overall average)	9.3	0.3
Hydro efficiency improvements	4.9	None
Small hydro 1	8.3	0.2
Small hydro 2	10.4	0.2
Small hydro 3	14.3	0.3
Small hydro 4	17.3	0.4
Solar	19.6	0.4
Wind	1.9	0.4
Nuclear	1.8	0.9
Conservation (overall average)	41.7	None
Conservation (res. space heat: Ex. SF)	77.9	None
Conservation (res. space heat: Ex. MF)	74.4	None
Conservation (res. space heat: New SF)	79.2	None
Conservation (res. space heat: New MF)	81.2	None
Conservation (res. space heat: New man.)	55.0	None
Conservation (res. appl.: refrigerators)	18.7	None
Conservation (res. appl.: freezers)	23.3	None
Conservation (res. appl.: water heaters)	18.1	None
Conservation (com: ex bldgs disc.)	30.2	None
Conservation (com: ex bldgs lost opp.)	20.2	None
Conservation (com: new bldgs lost opp.)	19.6	None
Conservation (industrial)	21.9	None
Conservation (agricultural)	22.5	None

(a) Estimate is for municipal solid waste plant. No data for wood-fired cogeneration operations employment were found.

TABLE S.2. Land-Use Impacts Summary

Resource	Construction Land Use (acres per MW capacity)	Operations Land Use (acres per MW capacity)
Pulverized coal	1.0	0.2
Atmospheric fluidized bed coal	1.5	0.2
Coal gasification	0.6	0.2
Cogeneration (overall average)	1.7	NQ
Cogeneration (wood-fired)	2.1	NQ
Cogeneration (municipal solid waste)	1.6	NQ
Combined cycle combustion turbine	0.1	NQ
Geothermal	0.2	NQ
Hydroelectric (overall average)	NQ	NQ
Hydro efficiency improvements	None	None
Small hydro 1	NQ	NQ
Small hydro 2	NQ	NQ
Small hydro 3	NQ	NQ
Small hydro 4	NQ	NQ
Solar	3.0	None
Wind	5.9	None
Nuclear	1.74	NQ
Conservation (overall average)	None	None
Conservation (res. space heat: Ex. SF)	None	None
Conservation (res. space heat: Ex. MF)	None	None
Conservation (res. space heat: New SF)	None	None
Conservation (res. space heat: New MF)	None	None
Conservation (res. space heat: New man.)	None	None
Conservation (res. appl.: Refrigerators)	None	None
Conservation (res. appl.: Freezers)	None	None
Conservation (res. appl.: Water heaters)	None	None
Conservation (com: ex bldgs disc.)	None	None
Conservation (com: ex bldgs lost opp.)	None	None
Conservation (com: new bldgs lost opp.)	None	None
Conservation (industrial)	None	None
Conservation (agricultural)	None	None

NQ = Not quantified.

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1.0 INTRODUCTION

This report describes work conducted by the Pacific Northwest Laboratory (PNL) to assist the Bonneville Power Administration (Bonneville) in evaluating the impacts of new power resources. This report focuses on impacts to employment and land use that would result from the implementation of different energy resource alternatives that Bonneville is considering using to meet growing electric energy needs in the Pacific Northwest. These alternatives are described in Bonneville's Resource Program Environmental Impact Statement (RPEIS) (BPA 1991).

This report is organized as follows. Chapter 2 describes the spreadsheet analyses methodology used to assess each of the resource alternatives. Chapter 3 through 12 describe the calculations and assumptions used to estimate impacts for each energy resource. Each resource description begins with a summary table of the impacts for that resource. The remainder of the resource description is broken down by construction and operation. Within these divisions data are presented on direct employment and on land use impacts. In addition, the construction discussions are preceded with data on the duration and scheduling of construction, a critical factor in evaluating impacts. Information on the breakdown of the labor impacts by skill mix is presented for pulverized coal (construction only), combustion turbines (operations only), and geothermal (operations only). Employment multipliers are presented for pulverized coal. No multipliers were located for the other resources, and hence all employment impacts are direct employment impacts.

Chapter 13 is references. The appendix show the development of the assumptions on which the analyses were based.

2.0 ANALYSIS METHODOLOGY

The following analyses were used to estimate impacts for each of the alternatives. For operation employment impacts for cogeneration, we used the factor from natural gas-fired combined-cycle combustion turbines. We found no estimate of employment needs for natural gas-fired cogeneration, which is the fuel Bonneville assumes that all cogeneration will employ for purposes of the EIS analysis.

Estimates of operations employment were a simple matter of multiplying the factor for each resource by the average megawatts of generation (or load reduction) expected for each energy resource type in each alternative. In this approach we assume that the annual generation rate in average megawatts accounts for the quantity of time that operation employees would be affected by Bonneville actions. Conservation resources (rather than the Emphasize Conservation Alternative) do not result in operations employment in our analysis.

Construction employment is a one-time event. Once a particular plant is constructed, or a conservation measure is installed, construction employment ends. Therefore, estimates of construction employment required that we address only new plants constructed in any given time period. To estimate new construction, we calculated the differences in generation between each year from 1991 to 2010. We assume that increased generation, over and above that reported in any previous year, results from new construction. Even though we do not accurately determine when a new plant is built, this approach does capture the employment resulting from construction as new electricity generation capacity is put in place to generate average megawatts. This approach addresses the energy requirements of Bonneville.

For consistency with the analysis of other types of impacts, we sum the effects to show impacts for the three study years of 1991, 2000, and 2010. Impacts that appear to occur in 1991 represent all plant construction up to that time. Employment from conservation activities occurring prior to 1991 is not estimated. Impacts that are shown for the year 2000 include those occurring from both new plant construction and conservation from 1992 through

2000. Impacts that are shown for 2010 include those occurring from both new plant construction and conservation from 2001 through 2010.

3.0 PULVERIZED COAL

A summary of the impacts of the construction and operation of pulverized coal plants on employment and land use is shown in Table 3.1. Sections 3.1 and 3.2 provide detailed discussions of how these impacts were determined.

TABLE 3.1. Resource Summary for Pulverized Coal Plants

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	4.7	1.0
Operation	0.5	0.2

-
- (a) Construction is in employee years per megawatt capacity; operation is in employees per year per megawatt capacity.
- (b) Construction is in total acres disturbed per megawatt capacity; operation is in acres disturbed per year per megawatt capacity.

3.1 CONSTRUCTION

This section discusses the scheduling and duration of 19 different coal plant construction projects; the direct employment requirements of 14 coal plant construction projects; the skill mix of the construction workers at three coal plant construction projects; the employment multipliers estimated by four different studies; and the construction land impacts of seven different coal plants.

3.1.1 Schedule and/or Duration

The scheduling and duration of a major construction project is an important factor in determining the level of impact from the project, especially in rural, sparsely populated areas. The data used came from a number of sources dealing with the duration of construction for coal plants. On average, for the 19 coal plants for which construction duration data was collected, the project took 79.58 months to complete, or 0.12 months per megawatt. The plant capacity ranged in size from 270 MW to 1,500 MW. The collected data is summarized in Table 3.2.

TABLE 3.2. Coal Plant Construction Duration

<u>Capacity (MW)</u>	<u>Duration (months)</u>	<u>Months per MW</u>	<u>Source</u>
1,000	72	0.07	DRI 1982
504	60	0.12	DRI 1982
550	60	0.11	DRI 1982
1,500	84	0.06	DRI 1982
1,180	120	0.10	DRI 1982
1,200	72	0.06	DRI 1982
600	72	0.12	DRI 1982
700	72	0.10	DRI 1982
700	108	0.15	DRI 1982
500	84	0.17	OTA 1985
270	72	0.27	BPA 1985
540	84	0.16	BPA 1985
1,300	84	0.06	BPA 1985
1,300	96	0.07	BPA 1987
540	72	0.13	BPA 1987
270	60	0.22	BPA 1987
550	84	0.15	ECO Northwest 1983
500	72	0.14	NWPPC 1989a
1,206	84	0.07	NWPPC 1989a
785	80	0.12	Average

A more refined estimate of construction duration is obtained by classifying the plants into three capacity categories: less than 500 MW; 500 to 999 MW; and 1,000 MW or over. Table 3.3 shows the average duration of construction, in both months and months per megawatt, for the three size categories.

TABLE 3.3. Coal Plant Construction Duration by Capacity

<u>Average Construction Capacity (MW)</u>	<u>Average Construction Duration (months)</u>	<u>Duration (months/MW)</u>
< 500	66.0	0.24
500 to 999	76.8	0.14
1,000 +	87.4	0.07

3.1.2 Direct Employment Schedule

A number of sources cite employment impacts for conventional coal. At the most disaggregated level, the estimate derived in a recent Worldwatch Institute report (Flavin and Lenssen 1990) is significant. This study estimates the direct employment impact of coal-fired electricity generation to be 116 jobs per thousand gigawatt-hours annually, which includes the impact of coal mining, plant construction, and facility operation.

Fourteen estimates of construction employee years per MW capacity are developed below. The average of all the estimates is 4.7; the range is 1.6 to 8.3 years per MW.

Bonneville's Comparative Electric Generation Study (BPA 1987) presents estimates of construction manhours for three different size plants. This allows calculation of the employee years per MW, assuming a 2,000 hour employee year, as shown in Table 3.4. On average, the three plants required 4.5 construction employee years per MW capacity, although this appears to be inversely related to the size of the plant.

TABLE 3.4. Construction Manhours for Three Different Plant Sizes

<u>Total Capacity (MW)</u>	<u>Configuration</u>	<u>Construction Manhours</u>	<u>Manhours per MW</u>	<u>Employee Years per MW</u>
1,300	two 650-MW units	9,740,212	7,492	3.7
540	two 270-MW units	5,106,333	9,546	4.7
270	one 270-MW unit	2,762,622	10,232	5.1

An ECO Northwest report (ECO Northwest 1983) for Bonneville on the effects of the 550-MW coal-fired generating plant at Boardman, Oregon, estimates peak construction employment at 1,566, and breaks the average annual construction employment down as shown in Table 3.5.

TABLE 3.5. Average Annual Employment During Construction of 550-MW Coal Plant at Boardman

<u>Year</u>	<u>Avg. Annual Direct Employment</u>
1975	20
1976	240
1977	370
1978	680
1979	1,043
1980	1,045
1981	430
1982	160

Summing the employment figures results in a total construction employee-years of 3,988, or approximately 7.3 employee-years per megawatt of capacity.

An EPRI report prepared by the Denver Research Institute (DRI 1982) analyzed nine coal-fired plants. The institute found that, while the bulk of the socioeconomic effects of the plants were a result of the influx of construction workers, the level of peak construction was rarely predicted successfully ahead of time. Table 3.6 gives the capacity, construction manhours, employee years per MW capacity, and peak labor force per MW capacity for each of the coal-fired plants analyzed in the study. The average plant had a capacity of 898 MW and required 4.4 employee years per MW to build. At peak construction employment levels, the average plant employed 2.2 workers per megawatt capacity.

TABLE 3.6. Employment Data for Construction of Nine Coal Plants

<u>Plant</u>	<u>Capacity (MW)</u>	<u>Manhours (Total)</u>	<u>Employee Years (per MW)</u>	<u>Peak Employment (Employees per MW)</u>
Coal Creek, ND	1,000	8,297,000	4.1	2.1
Clay Boswell, MN	500	4,165,968	4.2	3.1
Boardman, OR	550	4,606,760	4.2	2.7
Laramie River, WY	1,500	11,064,000	3.7	2.4
Newton, IL	1,180	8,348,500	3.5	1.2
Fayette, TX	1,200	3,793,000	1.6	0.7
Homer City #3, PA	600	4,809,500	4.0	2.1
Coronado #1 & #2, AZ	700	11,550,000	8.3	3.7
Cholla #2, #3, & #4, AZ	850	10,689,600	6.3	1.7
Average	898	7,480,481	4.4	2.2

Finally, the Office of Applied Energy Studies at Washington State University is cited in a Charles River Associates report (Charles River Associates 1984) as estimating that construction of coal plants directly generates 5 employee years per million 1983 dollars invested, or 4.1 years per one million 1989 dollars. Estimates of capital costs from a number of sources indicate that the average capital cost for construction of a pulverized coal plant is approximately \$1.242 million in 1989 dollars per MW capacity. Therefore, the Charles River estimate implies that construction of pulverized coal plants results in 5.1 employee years per MW of capacity in direct employment impacts.

3.1.3 Skill Mix of Construction Employees

Data on the skill mix of the coal plant construction work force was also located in the Charles River Associates report (1984). The document provides data on the skill mix of the construction employees and its change over time. Table 3.7 gives the average skill mix of the construction work force at the Coal Creek Station coal plant (located in North Dakota), during the 1975 to 1979 period.

TABLE 3.7. Work Force Mix During Construction of Coal Creek Station Coal Plant

<u>Craft</u>	<u>Percent of Total Work Force (Quarterly Average)</u>
Ironworker	14%
Electrician	13%
Pipefitter	12%
Operator	12%
Laborer	11%
Boilermaker	9%
Supervision	9%
Carpenter	8%
Sheetmetal	4%
Millwright	1%
Cement Finisher	1%
Insulator	1%
Teamster	1%
Bricklayer	1%
Painter	1%
Total	100%

Table 3.8 gives the skill mix for each quarter during construction of the Coal Creek Station Coal Plant, a period lasting from the third quarter of 1975 to the second quarter of 1979.

A 1979 study (Murdock and Leistritz 1979) categorized skills at two coal plants, one in North Dakota in 1975 and one in Wyoming in 1976. These skill mixes are presented in Tables 3.9 and 3.10. Included in the data are the average worker wage, the average worker age, and the length of time employed at this and previous jobs.

TABLE 3.8. Work Force Mix for Each Quarter of Construction

Craft	Percent of Total Work Force															
	1975		1976				1977				1978				1979	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Ironworker	6	9	35	24	30	24	9	17	14	10	10	9	7	5	5	5
Electrician	5	9	7	5	4	6	4	10	14	18	16	17	21	27	26	26
Pipefitter	7	3	7	3	4	9	9	8	13	17	18	17	20	20	23	21
Operator	33	32	13	25	14	9	10	8	9	8	7	7	6	4	4	3
Laborer	23	8	16	18	14	14	13	12	10	8	7	9	8	7	7	8
Boilermaker	0	5	0	2	3	8	14	14	14	15	16	14	12	11	10	9
Supervision	11	17	11	9	7	6	7	8	8	8	8	7	7	8	9	9
Carpenter	10	6	7	9	12	12	15	10	8	6	7	7	6	3	4	5
Sheetmetal	0	3	0	0	7	7	10	4	3	3	3	4	4	5	5	6
Millwright	0	0	0	0	0	0	0	2	2	3	2	3	2	3	3	3
Cement Finisher	1	3	2	2	3	1	2	2	1	1	1	1	1	0	1	0
Insulator	0	0	0	0	0	0	0	0	0	2	3	3	3	3	4	4
Teamster	3	4	2	2	1	3	2	1	1	1	0	0	1	1	0	0
Bricklayer	0	0	0	0	1	1	4	2	1	1	0	1	1	0	0	0
Painter	0	0	0	0	0	0	0	1	1	1	0	1	2	2	2	2
Total	99	99	100	99	100	100	99	99	99	102	98	100	101	99	103	101

TABLE 3.9. Construction Work Force at North Dakota Coal Plant

<u>Job Classification</u>	<u>Percent of Work Force</u>	<u>Average Hourly Wage (1975 dollars)</u>	<u>Average Age (years)</u>	<u>Length Employed Present Job (years)</u>	<u>Length Employed Previous Job (years)</u>
Supervisory	6.8	7.97	46.0	8.7	2.3
Professional-technical	8.0	8.58	33.4	2.2	2.3
Craftsmen:	61.8	8.25	36.4	1.2	2.0
Electrician	11.4	9.12	38.2	0.5	1.8
Mechanics & welders	3.8	8.14	36.8	2.8	2.1
Pipe fitter	35.6	8.04	35.1	0.9	1.9
Power Plant Operator	--	--	--	--	--
Technician	--	--	--	--	--
Other	11.0	8.04	38.4	2.1	2.6
Laborer	15.2	5.14	32.1	1.7	1.9
Operatives:	4.9	7.05	44.2	6.5	2.1
Heavy equipment	--	--	--	--	--
Other	--	--	--	--	--
Clerical & Other	3.4	3.78	25.4	1.5	1.7
Total	100.0	7.39	36.3	2.1	2.0
N =	264				

TABLE 3.10. Construction Work Force at Wyoming Coal Plant

<u>Job Classification</u>	<u>Percent of Work Force</u>	<u>Average Hourly Wage (1976 dollars)</u>	<u>Average Age (years)</u>	<u>Length Employed Present Job (years)</u>
Supervisory	6.3	12.14	37.8	7.7
Professional-technical	3.5	8.04	33.4	6.0
Craftsmen:	45.7	8.21	34.3	3.8
Electrician	4.8	8.18	34.9	3.9
Mechanics & welders	17.9	8.42	34.1	3.7
Pipe fitter	--	--	--	--
Power Plant Operator	13.4	8.16	33.0	4.3
Technician	5.1	8.09	35.0	3.4
Other	4.5	7.68	37.3	3.5
Laborer	11.4	5.11	27.3	1.2
Operatives:				
Heavy equipment	25.3	7.52	34.3	2.7
Other	3.3	6.23	26.2	0.7
Clerical & Other	4.5	6.00	33.8	3.1
Total	100.0	7.60	33.4	3.7
N =	396			

3.1.4 Employment Multiplier(s)

Employment multipliers refer to the employment created when direct employees (construction workers, supervisors) spend their incomes. The employment multiplier is the number of indirect jobs created for each direct job. A similar concept is the income multiplier, which is the number of dollars generated for each dollar paid to direct employees. Both are presented in this section.

A Charles River Associates study (1984) cites 31 induced employee years per one million 1983 dollars invested in coal construction. Using the gross national product (GNP) price deflator, these figures convert to 25 induced employee years per one million 1989 dollars.

In contrast, a Denver Research Institute study (1982) finds that the local service-to-construction worker ratio rarely exceeded 0.2 in the 12 case studies analyzed, nine of which were coal plants. This report states "In general, local service-to-basic ratios are lower in less well developed areas where a higher proportion of purchases are made outside the impact area.... Multipliers are lowest in Boardman, Laramie River, and Coronado.... These ... areas are the most sparsely populated."

In the same study, the Denver Research Institute (1982) finds the local service-to-basic construction employment ratios given in Table 3.11 to be generally applicable.

TABLE 3.11. Ratio of Local Service Jobs Created for Each Coal Plant Construction Job

<u>Type of Impact Area</u>	<u>In-Migrating Construction Workers</u>	
	<u>Ratio to Peak</u>	<u>Ratio to Annual Average</u>
Rural, sparsely populated, no large trade center within impact area	0.1-0.2	0.2-0.3
More urbanized, moderate population densities	0.1-0.2	0.3-0.4
Fringe of metropolitan area	0.2-0.3	0.4-0.5

Table 3.12 shows the ratio of direct to indirect employment found in the ECO Northwest survey (1983) of the coal plant at Boardman.

TABLE 3.12. Ratio of Direct to Indirect Employment at Boardman Plant

<u>Year</u>	<u>Direct Employment</u>	<u>Indirect Employment</u>	<u>Implied Multiplier</u>
1975	20	4	0.20
1976	240	48	0.20
1977	370	74	0.20
1978	680	136	0.20
1979	1,043	219	0.21
1980	1,045	209	0.20
1981	430	86	0.20
1982	160	240	1.50

Operation at this plant began in 1980, so the multipliers for 1980, 1981, and 1982 are for both operating and construction personnel.

3.1.5 Construction Land-Use Impacts

Construction land-use impacts consist of the area that must be cleared for the plant. Information on the actual land area required by a plant is scarce and the information that does exist is quite varied. A number of sources were used to derive the estimate of 1.04 acres per MW capacity. The development of this estimate is described below.

A PNL report for Bonneville (Baechler, Fickeisen, and Hendrickson 1990) reports that plants typically occupy 40 acres for a 350-MW plant, and 700 acres for a 2,100-MW plant. This works out to 0.11 and 0.33 acres per MW, respectively. The same source indicates that the 550-MW plant at Boardman occupies 3,525 acres, or 6.41 acres per MW. Baechler indicates that the Boardman plant occupies an unusually large area. Baechler also states that several thousand additional acres are required for ash and sludge disposal.

The Office of Technology Assessment (OTA 1985) reports a pulverized coal plant of 714 MW as occupying 640 acres, or 0.90 acres per MW.

Bonneville's Comparative Electric Generation Study (BPA 1987) gives land use information for three pulverized coal plants, as shown in Table 3.13.

TABLE 3.13. Acreage Requirements for Pulverized Coal Plants Showing Area Required for Disposal

<u>Capacity (MW)</u>	<u>Site Area (acres)</u>	<u>Disposal Area (acres)</u>	<u>Total Acres per MW</u>
1,300	400	1,130	1.18
540	300	450	1.39
270	380	250	2.33

Table 3.14 incorporates these various sources of land-use data.

TABLE 3.14. Acreage Requirements for Pulverized Coal Plants

<u>Capacity (MW)</u>	<u>Total Area (acres)</u>	<u>Acres per MW</u>	<u>Source</u>
270	630	2.33	BPA 1987
350	40	0.11	Baechler, Fickeisen & Hendrickson 1990
540	750	1.39	BPA 1987
550	3,525	6.41	Baechler, Fickeisen & Hendrickson 1990
714	640	0.90	OTA 1985
1,300	1,530	1.18	BPA 1987
2,100	700	0.33	Baechler, Fickeisen & Hendrickson 1990

With the exception of the Boardman plant, the acres per MW figure varies between 0.11 and 2.33, with a mean of 1.04.

3.2 OPERATION

Operations impacts for all types of coal generation include both the impacts directly attributable to the generating plant and the impacts attributable to the mining operation that supplies the coal. This section begins with a discussion of the employment impacts of the generating plant, and is followed by a discussion of the impacts due to the coal mining operation. A brief discussion of employment multipliers is followed by a

description of the land-use impacts attributable to operation of the generating plant. As the land-use impacts of the site itself have already been discussed in Section 3.1.5, this section deals with the land-use impacts attributable to the coal mining operation.

The total operations employment impact of 0.46 employees per year per MW capacity is obtained by summing the main facility estimate of 0.33 employees and the coal mining estimate of 0.13 employees. The derivation of these estimates is described in the next two sections.

3.2.1 Main Facility Direct Employment

Reports by Bonneville (BPA 1987) and the U.S. Department of Energy (DOE 1983) contain estimates of the number of operations and management (O&M) workers per MW of capacity. On average, 0.33 O&M employees per MW of capacity are employed each year. This estimate is consistent with the three estimates developed below, and was chosen to represent this resource.

The Bonneville report cited also provides skill breakdowns for three pulverized coal case studies as presented in Table 3.15. This table shows an inverse relationship between number of employees per MW capacity and capacity. The distribution of total O&M employees over the job classifications remains fairly stable; however, operators account for 39% to 40% of the O&M work force in all three plants, while maintenance represents 32% to 36%.

The estimate of 0.33 employees per MW capacity is consistent with an International Energy Agency report (1989) which estimates that a 1,144-MW coal plant consisting of two units will require 301 O&M employees, or 0.3 per MW capacity. This report states that labor accounts for 29% of fixed O&M costs in coal plants.

Two studies by the Northwest Power Planning Council (NWPPC 1989a and NWPPC 1989d) and one by Bonneville (BPA 1985) provide estimates of the fixed O&M costs per MW of capacity associated with 10 pulverized coal plants, as presented in Table 3.16. Using the average annual labor costs for pulverized coal operators of \$37,492 (See the Appendix to this report), an average of 0.33 O&M employees per MW was calculated. Non labor costs are extraneous to our analysis. All costs have been inflated to 1989 dollars using the GNP price deflator.

TABLE 3.15. Number of Employees per Megawatt of Plant Capacity by Labor Category

O&M Labor Category	Case Study 1			Case Study 2			Case Study 3		
	Total	per MW	%	Total	per MW	%	Total	per MW	%
Capacity (MW)	1300			540			270		
Operators	100	0.08	40	80	0.15	40	60	0.22	39
Maintenance	90	0.07	36	70	0.13	35	50	0.19	32
Gate Security	12	0.01	5	10	0.02	5	10	0.04	6
Labs/Stores	13	0.01	5	10	0.02	5	10	0.04	6
General Help	25	0.02	10	20	0.04	10	15	0.06	10
Supervisors	11	0.01	4	9	0.02	5	9	0.03	6
Total	251	0.19		199	0.37		154	0.57	

TABLE 3.16. O&M Costs for Coal Plant Operation

Source	Capacity (MW)	Fixed O&M Costs (\$/kW/yr)	Labor O&M Costs (\$/MW/yr)	Total Employees per MW
BPA 1985	270	\$29	\$8,410	0.22
BPA 1985	540	\$20	\$5,800	0.15
BPA 1985	1,300	\$10	\$2,900	0.08
NWPPC 1989a	500	\$33	\$9,570	0.26
NWPPC 1989a	1,206	\$21	\$6,090	0.16
NWPPC 1989d	1,576	\$60	\$17,400	0.46
NWPPC 1989d	1,206	\$31	\$8,990	0.24
NWPPC 1989d	1,206	\$44	\$12,760	0.34
NWPPC 1989d	1,000	\$57	\$16,530	0.44
NWPPC 1989d	1,676	\$126	\$36,540	0.97
Average	1,048	\$43	\$12,470	0.33
Max	1,676	\$126	\$36,540	0.97
Min	270	\$10	\$2,900	0.08

3.2.2 Coal Mine Direct Employment

The Energy Technology Characterizations Handbook (DOE 1983) estimates that a western surface coal mine with a preparation plant requires 1.53 workers per quadrillion Btu produced, assuming a heat rate of 8,750 Btu per pound of coal. Given Bonneville's assumption of a heat rate of 10,856 Btu/kWh for a pulverized coal plant, we calculate mining employment impacts of 0.15 employees per MW of generation. Assuming a capacity factor of 0.8 results in an estimate of 0.12 mine employees per MW capacity per year. This plant capacity factor falls within the range of 0.75 to 0.80 that are frequently cited (DOE 1983, and BPA^(*)).

3.2.3 Employment Multiplier(s)

Overall, the semi-permanence of O&M jobs would lead us to expect a larger multiplier with O&M jobs than is associated with construction jobs.

Some evidence of the multipliers associated with O&M jobs can be gleaned from a report by ECO Northwest (1983) on economic impacts of the environmental effects of a coal-fired electric generator. While this source does not distinguish between construction and O&M jobs, it provides direct and indirect plant employment figures for the periods between 1975 and 1982 (the plant started operation in 1980). The multiplier is roughly constant at 0.20 from 1975 to 1981, and then rises sharply to 1.50 in 1982.

A Denver Research Institute study (1982) finds the multiplier associated with in-migrating operating employees to be between 0.3 and 0.8, depending on the type of impact area (see Table 3.17).

A reasonable estimate would appear to be 0.5 jobs created for every direct operations job.

3.2.4 Operation Land-Use Impacts

Operations land-use impacts consist of the land disturbed for coal mining and transportation. The land used to site the plant is discussed in Section 3.1.5.

(*) Bonneville Power Administration. 1990. Draft 1990 Generating Resources Supply Forecast. Bonneville Power Administration, Portland, Oregon.

TABLE 3.17. Multipliers for Indirect Jobs Associated with Plant Operations Employment

<u>Type of Impact Area</u>	<u>In-Migrating Operating Employees</u>
Rural, sparsely populated, no large trade center within impact area	0.3-0.5
More urbanized, moderate population densities	0.4-0.6
Fringe of metropolitan area	0.6-0.8

Bonneville determined a relationship between generation in aMW and coal mining land use for four Pacific Northwest power plants (BPA 1988). On average, 0.23 acres are disturbed annually per MW of generation. Assuming a load factor of 0.85 results in 0.19 acres per MW capacity. The data used in the development of the estimate is presented in Table 3.18.

TABLE 3.18. Relationship between Power Generation and Land Use

<u>Power Plant</u>	<u>Coal Consumption (thousands of tons per MW)</u>	<u>Land Disturbance (acres per year per thousand tons of coal)</u>	<u>Land Disturbance (acres per year per MW)</u>
Colstrip	5.716	0.0187	0.1067
Boardman	5.882	0.0170	0.1002
Centralia	5.948	0.0588	0.3495
Bridger	5.251	0.0664	0.3486
Average	5.699	0.0402	0.226

4.0 ATMOSPHERIC FLUIDIZED BED COAL

A summary of the impacts of the construction and operation of atmospheric fluidized bed coal (AFBC) plants on employment and land use is shown in Table 4.1. Sections 4.1 and 4.2 discusses these impacts.

TABLE 4.1. Resource Summary for Atmospheric Fluidized Bed Coal Plants

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	5.1	1.5
Operation	0.7	0.2

- (a) Construction is in employee years per megawatt capacity;
operation is in employees per year per megawatt capacity.
(b) Construction is in total acres disturbed per megawatt capacity;
operation is in acres disturbed per year per megawatt capacity.

4.1 CONSTRUCTION

The construction schedule for an AFBC plant, the employment schedule, and the land-use impacts during construction are discussed below.

4.1.1 Schedule and/or Duration

Bonneville's Comparative Electric Generation Study (BPA 1987) estimates a six-year construction time for a 113-MW-capacity AFBC plant located in Boardman, Oregon (see Table 4.2). The construction period calculates to 1.6 months per MW capacity.

TABLE 4.2. Construction Cash Flow

<u>Year</u>	<u>Cumulative Percent of Total Construction Expenditure</u>
1	0.1
2	8.0
3	26.0
4	73.0
5	95.0
6	100.0

4.1.2 Direct Employment Schedule

The same Bonneville study (1987) estimates direct construction employment to be 1,148,877 manhours, or 10,167 manhours per MW capacity. The employment would be distributed over the life of the project in accordance with the above schedule. Assuming 2,000 hours in an employee-year, this works out to 5.08 employee years per megawatt capacity, exactly the same as was estimated for the pulverized coal plant from a collection of 14 sources.

4.1.3 Construction Land-Use Impacts

We calculated the land-use impacts to be approximately 1.5 acres per MW for an AFBC plant.

In its report, "Comparative Electric Generation Study: Coal-Fired Power Plants," (BPA 1987) Bonneville describes a 113-MW-capacity AFBC plant located in Boardman, Oregon, as requiring 150 acres, or 1.33 acres per MW capacity. An additional 100 acres would need to be prepared for the disposal of ash and scrubber sludge. This brings the total acreage requirement to 2.21 acres per MW capacity.

Alternatively, the Energy Technology Characterizations Handbook (DOE 1983) cites a 560-MW-capacity AFBC plant as requiring 442 acres, or 0.79 acres per MW capacity.

By averaging the figures from the DOE and Bonneville reports, we determined the impact to be 1.5 acres per MW.

4.2 OPERATION

Operations impacts for all types of coal generation include both the impacts directly attributable to the generating plant and the impacts attributable to the mining operation that supplies the coal. For an AFBC plant, 0.58 employees per MW are required to run the plant, and an additional 0.12 employees per MW are required for the mining operation, for a total operations requirement of 0.70 employees per MW capacity. The derivation of the estimates is described below.

4.2.1 Main Facility Direct Employment

Bonneville's Comparative Electric Generation Study (BPA 1987) reported that a total of 66 employees are required to run an AFBC plant, or 0.58 operating employees per MW capacity. These employees are specified by skill mix in Table 4.3.

TABLE 4.3. Employee Mix for AFBC Plant

<u>O&M Labor Category</u>	<u>Total</u>	<u>Employees per MW</u>	<u>Percent</u>
Operators	24	0.21	36%
Maintenance	21	0.18	32%
Gate Security	4	0.03	6%
Laboratories/Stores	4	0.03	6%
General Help	5	0.04	8%
Supervisors	8	0.07	12%
Total	66	0.58	100%

4.2.2 Coal Mine Direct Employment

The heat rate assumed by Bonneville for the AFBC plant is 9,885 Btu/kWh. A mine employment estimate can be derived by assuming that the coal mine employment required by this type of plant will be less than that required by a conventional pulverized plant in accordance with the ratio of their heat rates. The pulverized plant has a heat rate of 10,856 Btu/kWh and requires 0.13 mine employees per MW of capacity, assuming a 0.8 capacity factor. The AFBC plant can therefore be expected to require 0.12 employees per MW of capacity.

4.2.3 Operation Land-Use Impacts

The operations land-use impacts consist of the land used by the coal mine supplying the plant. The land used to site the plant is discussed in Section 4.1.3.

The mine land area required is assumed to differ from that required by a conventional pulverized coal plant by the ratio of the heat rates. The heat rate for an AFBC plant is assumed by Bonneville to be 9,885 Btu/Kwh, while the

rate for a pulverized coal plant is assumed by Bonneville to be 10,856 Btu/kWh. A pulverized coal plant is estimated to require 0.19 acres per MW capacity per year (see Section 3.2.4). An AFBC plant should therefore require 0.17 acres per MW capacity per year.

5.0 COAL GASIFICATION

A summary of the impacts of the construction and operation of integrated gasification combined-cycle (IGCC) plants on employment and land use is shown in Table 5.1. Sections 5.1 and 5.2 provide detailed discussions of how these impacts were determined.

TABLE 5.1. Resource Summary for Coal Gasification Plants

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	5.7	0.6
Operation	0.9	0.2

- (a) Construction is in employee years per megawatt capacity;
operation is in employees per year per megawatt capacity.
(b) Construction is in total acres disturbed per megawatt capacity;
operation is in acres disturbed per year per megawatt capacity.

5.1 CONSTRUCTION

The construction schedule for an IGCC plant, the employment schedule, and the land-use impacts during construction are discussed below.

5.1.1 Schedule and/or Duration

The Comparative Electric Generation Study: Coal Gasification report (BPA 1986) estimates a 39-month construction time for a 451-MW-capacity IGCC coal plant located in Boardman, Oregon. A construction time of 0.09 months per MW capacity is calculated. The construction would proceed according to the schedule shown in Table 5.2.

TABLE 5.2. Construction Cash Flow

<u>Year</u>	<u>Percent of Total Construction Expenditure</u>
1	6.0%
2	37.4%
3	85.9%
4	100.0%

The Office of Technology Assessment (1985) estimates 5 to 10 years construction time for a 700-MW-capacity plant, or 0.09 to 0.17 months per MW.

5.1.2 Direct Employment Schedule

Direct construction employment is estimated to be 5,114,000 manhours, or 11,339 manhours per MW capacity (BPA 1986). This is equivalent to 5.7 employee years per MW capacity, assuming a 2,000-hour employee year. The employment would be distributed over the life of the project in accordance with the above schedule.

5.1.3 Construction Land-Use Impacts

The Comparative Electric Generation Study: Coal Gasification report (BPA 1986) describes a 451-MW-capacity IGCC coal plant located in Boardman, Oregon, as requiring 150 acres upon completion of all four phases, resulting in a figure of 0.33 acres per MW capacity.

In a report for Congress, the Office of Technology Assessment estimates that a 625-MW-capacity plant would require 300 to 600 acres, or 0.48 to 0.96 acres per MW capacity (OTA 1985).

Averaging the figures from these sources yields a land-use impact of 0.59 acres per MW.

5.2 OPERATION

The total direct operation employment figure of 0.88 employees per MW was derived from the addition of the main facility direct employment figure (0.77) and the coal mine direct employment figure (0.11). These figures are discussed below.

5.2.1 Main Facility Direct Employment

In its coal gasification report (BPA 1986), Bonneville specifies operating and maintenance costs for operating labor, maintenance labor, and administrative and support labor. Using the average salary for pulverized coal operation of \$37,492 (see the Appendix), an estimate of 0.77 operations employees per MW capacity per year can be derived. This data is presented in Table 5.3. All costs have been inflated to 1989 dollars using the GNP price

deflator. For more detail on the assumptions used in these calculations, see Section 3.2.1.

TABLE 5.3. Operations Employment Mix Cost and Levels at a IGCC Plant

<u>Labor Type</u>	<u>Phase 4 Cost (1989 \$/MW/yr)</u>	<u>Employees per MW Capacity per yr</u>
Operating	\$7,300	0.19
Maintenance	\$14,767	0.39
Admin. & Support	\$6,622	0.18
Total	\$28,689	0.77

5.2.2 Coal Mine Direct Employment

The heat rate assumed by Bonneville for the IGCC plant is 9,270 Btu/kWh. A mine employment estimate can be derived by assuming that the coal mine employment required by this type of plant will be less than that required by a conventional pulverized plant in accordance with the ratio of their heat rates. The pulverized plant has a heat rate of 10,856 Btu/kWh and requires 0.13 mine employees per MW of capacity, assuming a 0.85 load factor. The IGCC plant can therefore be expected to require 0.11 employees per MW of capacity.

5.2.3 Operations Land-Use Impacts

The operations land-use impacts consist of the land used by the coal mine required to supply the plant. The land used to site the plant is discussed in Section 5.1.3.

The mine land area required is assumed to differ from that required by a conventional pulverized plant by the ratio of the heat rates. The heat rate for a coal gasification plant is assumed by Bonneville to be 9,270 Btu/kWh, while the rate for a pulverized coal plant is assumed by Bonneville to be 10,856 Btu/kWh. A pulverized coal plant is estimated to require 0.19 acres per MW capacity per year (see Section 3.2.4). A coal gasification plant should therefore require 0.16 acres per MW capacity per year.

6.0 COGENERATION

A summary of the impacts of the construction and operation of cogeneration plants on employment and land use is shown in Table 6.1. Sections 6.1 and 6.2 provide detailed discussions of how these impacts were determined.

TABLE 6.1. Resource Summary for Cogeneration Plants

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
All:		
Construction	15.1	1.7
Operation	4.5	NQ
WOOD-FIRED:		
Construction	9.6	2.1
Operation	4.5 ^(c)	NQ
MUNICIPAL SOLID WASTE:		
Construction	24.1	1.6
Operation	4.5	NQ

(a) Construction is in employee years per megawatt capacity; operation is in employees per year per megawatt capacity.

(b) Construction is in total acres disturbed per megawatt capacity; operation is in acres disturbed per year per megawatt capacity.

(c) Estimate is for a MSW plant. No data for wood-fired plant employment were found.

NQ = Not quantified.

6.1 CONSTRUCTION

The construction schedule for cogeneration plants, the employment schedule, and the land-use impacts during construction are discussed below.

6.1.1 Schedule and/or Duration

Estimates of the duration of construction for cogeneration plants vary widely. The full range of estimates is given below.

In its report on Generating Resources Supply Curves (BPA 1985), Bonneville examined five cogeneration options: three wood-fired, one wood-fired combustion turbine, and one municipal solid waste-fired (MSW). The wood-fired plants were all 12-MW capacity, and were projected to take 24 months to build. The wood-fired CT was 22-MW capacity, and expected to take 12 months to build. The MSW was 9.2-MW capacity and was expected to take 36 months to build. The months-per-MW figures for each plant are 0.5, 1.8, and .25, respectively.

A Northwest Power Planning Council Staff Issue Paper on biomass resources (NWPPC 1989f) estimates a MSW incinerator with 2-MW capacity would take 18 months to build, or 9 months per MW.

The Office of Technology Assessment (OTA 1985) estimates a 60-MW-MSW plant would take 5 to 7 years to build or between 1.0 and 1.2 months per MW.

These estimates are summarized in Table 6.2.

TABLE 6.2. Construction Duration for Cogeneration Plants

<u>Type of Plant</u>	<u>Capacity (MW)</u>	<u>Months of Construction</u>	<u>Months per MW</u>	<u>Source</u>
Wood fired	12	24	2.0	BPA 1985
Wood fired	12	24	2.0	BPA 1985
Wood fired	12	24	2.0	BPA 1985
Wood fired CT	22	12	0.5	BPA 1985
MSW	9	36	4.0	BPA 1985
MSW	2	18	9.0	NWPPC 1989f
MSW	60	60-84	1.0-1.4	OTA 1985

6.1.2 Direct Employment Schedule

No explicit employment impact data are available for cogeneration plants. An ECO Northwest report (ECO Northwest et al. 1986) predicts insignificant employment impacts from cogeneration plants fueled by mill waste, logging residue, and MSW-fueled cogeneration.

An extremely rough estimate of employment effects can be obtained through data on capital costs of various types of plants, given assumptions about the

fraction of capital costs devoted to labor and the average construction labor wage rate. It was assumed that 20% of capital costs go to construction labor, a ratio that was developed as the average for a variety of coal technologies (BPA 1987; BPA 1986). The estimate will be off by the extent that cogeneration construction is more or less labor intensive than coal plant construction. In addition, the average pulverized coal plant salary of \$37,492 (see the Appendix) is used to derive the employee years per MW figures. Figures were inflated using the GNP price deflator to obtain 1989 figures. Table 6.3 shows the derivations.

TABLE 6.3. Employment Levels and Costs During Construction of a Cogeneration Plant

<u>Plant Type</u>	<u>Capacity (MW)</u>	<u>Capital Cost 1989 \$/kW</u>	<u>Labor Cost 1989 \$/MW</u>	<u>Employee Years per MW</u>
Wood fired	12	\$1,207	\$241,400	6.4
Wood fired	12	\$2,024	\$404,800	10.8
Wood fired	12	\$2,905	\$581,000	15.5
Wood fired CT	22	\$1,136	\$227,200	6.1
Wood/ag. waste	30	\$1,750	\$350,000	9.3
MSW	9	\$4,102	\$820,400	21.9
MSW	2	\$6,629	\$1,325,800	35.4
MSW	60	\$2,841	\$568,200	15.1
Average	19.9	\$2,824	\$564,800	15.1
Wood-Fired Avg	17.6	\$1,804	\$360,800	9.6
MSW Average	23.7	\$4,524	\$904,800	24.1

6.1.3 Construction Land-Use Impacts

The construction land-use impacts from cogeneration consist of the land used to site the plant. Various sources (Baechler, Fickeisen, and Hendrickson 1990; ECO Northwest et al. 1986; OTA 1985) estimate the land required to site the plant at between 0.33 acres per MW and 5 acres per MW. The average being 1.7 acres. These estimates are given in Table 5.4. All sources agree that the plants would be located in industrial areas, limiting the land-use impacts from the siting of the plant.

TABLE 6.4. Acreage Requirements for Siting a Cogeneration Plant

<u>Type</u>	<u>Capacity</u>	<u>Acres</u>	<u>Acres/MW</u>	<u>Source</u>
Biomass	12	25	2.1	ECO Northwest et al. 1986
MSW	10	10-50	1-5	ECO Northwest et al. 1986
MSW	10	10-15	1-1.5	Baechler, Fickeisen, and Hendricksen 1990
MSW	60	20	0.3	OTA 1985
Average:	23	16-27	1.1-2.2	
Biomass Average:	12	25	2.1	
MSW Average:	27	13-28	0.8-2.3	

6.2 OPERATION

The employment and land-use impacts during operation of a cogeneration plant are discussed below.

6.2.1 Direct Employment

An ECO Northwest study (ECO Northwest et al. 1986) estimates a 10-MW MSW plant would be operated by 45 employees and would displace some landfill employment. Ignoring the displacement effect results in 4.5 employees per MW capacity.

6.2.2 Operation Land-Use Impacts

The land-use impacts from operating a cogeneration plant include the impacts of the plant itself, and the impacts on the land from supplying fuel for the plant. The impacts of the plant site itself are discussed in Section 6.1.3. The land-use impacts of supplying fuel to the plant vary depending on the type of plant. Biomass plants require the removal of logging or agricultural waste from the land for fuel, while MSW plants burn wastes that would otherwise be disposed of, most likely in a landfill.

Biomass plants are cited (ECO Northwest et al. 1986; Baechler, Fickeisen, and Hendrickson 1990) as possibly reducing the productivity of forest lands by removing nitrogen-supplying logging residue from the land, although Baechler

(Baechler, Fickeisen, and Hendrickson 1990) states that only 10% to 25% of the fuel would come from logging residues, while the rest would come from mill waste.

7.0 COMBUSTION TURBINE

A summary of the impacts of the construction and operation of combined cycle combustion turbine plants on employment and land use is shown in Table 7.1. Sections 7.1 and 7.2 provide detailed discussions of how these impacts were determined.

TABLE 7.1. Resource Summary for Combustion Turbine Plants

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	1.4	0.2
Operation	0.1	NQ

(a) Construction is in employee years per megawatt capacity; operation is in employees per year per megawatt capacity.

(b) Construction is in total acres disturbed per megawatt capacity; operation is in acres disturbed per year per megawatt capacity.

NQ = Not quantified.

7.1 CONSTRUCTION

The construction schedule for combustion turbine plants, the employment schedule, and the land-use impacts during construction are discussed below.

7.1.1 Schedule and/or Duration

Several sources provide estimates on the duration of construction of a combustion turbine plant. These estimates range from 18 to 39 months or 0.08 to 0.20 months per MW capacity. The various estimates are given in Table 7.2.

A report published by Fluor provides a schedule for construction of a combined-cycle plant (Fluor Daniel, Inc. 1988). The schedule is presented in Table 7.3.

TABLE 7.2. Construction Duration for Combustion Turbine Plants

Type	Capacity (MW)	Months of Construction	Months per MW	Source
CC	452.2	39	0.09	Fluor Daniel Inc. 1988
CC	452	36	0.08	NWPPC 1989a
--	150	18	0.12	Baechler, Fickeisen, & Hendrickson 1990
--	150	30	0.20	OTA 1985
CC	321	36	0.11	BPA 1985
SC	304	24	0.08	NWPPC 1989a
SC	236	24	0.10	BPA 1985
Average	295	30	0.11	

CC = combined-cycle combustion turbine

SC = simple-cycle combustion turbine

TABLE 7.3. Construction Schedule for a Combined-Cycle Combustion Turbine Plant

Month	Cumulative Cash Flow (Millions of 1988 \$)			Total	Percent
	Phase 1	Phase 2	Phase 3		
3	0.4	8.6	0.3	9.3	4.1%
6	15.5	15.2	3.7	34.4	15.2%
9	26.9	21.8	10.3	59.0	26.0%
12	38.9	28.9	18.2	86.0	38.0%
15	51.1	39.2	28.1	118.4	52.3%
18	68.6	42.7	40.0	151.3	66.8%
21	76.4	46.0	54.4	176.8	78.1%
24	81.2	69.8	--	205.4	90.7%
27	82.2	--	--	206.4	91.1%
30	90.4	--	--	214.6	94.7%
33	95.9	--	--	220.1	97.2%
36	100.0	--	--	224.2	99.0%
39	102.3	--	--	226.5	100.0%
Year	Total	Percent			
1	86.0	38.0%			
2	205.4	90.7%			
3	224.2	99.0%			
4	226.5	100.0%			

7.1.2 Direct Employment Schedule

Fluor estimates total labor expenditures for construction of a combined-cycle combustion turbine to be \$25,119,791 in 1989 dollars, and to require 1,290,000 manhours (Fluor Daniel, Inc. 1988). These translate to \$55,550 per MW and 2,853 manhours per MW for a 452.2-MW-capacity plant. Assuming a 2,000-hour employee year results in an estimate of 1.4 employee years per MW capacity.

7.1.3 Construction Land-Use Impacts

Three sources provide estimates for land-use impacts. These site-construction land-use impacts consist of the area required to site the plant. The estimates of plant area are given in Table 7.4. The average is 0.16 acres per MW capacity.

TABLE 7.4. Acreage Requirements for Siting a Combined-Cycle Combustion Turbine Plant

<u>Capacity (MW)</u>	<u>Area (acres)</u>	<u>Acres per MW</u>	<u>Source</u>
452	75	0.17	Fluor Daniel, Inc. 1988
150	2-5	0.01-0.03	OTA 1985
150	44	0.29	Baechler, Fickeisen & Hendrickson 1990

7.2 OPERATION

The employment and land-use impacts resulting from operation of a combustion turbine plant are discussed below.

7.2.1 Direct Employment

Fluor supplies the most detailed source for operations employment figures in its report, Development of Combustion Turbine Capital and Operating Costs, (Fluor Daniel, Inc. 1988), which estimates a completed combined-cycle combustion turbine plant will require 0.07 operating employees per MW capacity (see Table 7.5).

TABLE 7.5. Employment Levels for Operation of a Combined-Cycle Combustion Turbine Plant

<u>Labor Category</u>	<u>Number of Employees</u>			<u>Phase 3 Employees per MW, 452.2 MW</u>
	<u>Phase 1</u>	<u>Phase 2</u>	<u>Phase 3</u>	
Operating Crew	2	3	20	0.04
Maintenance Crew	2	3	9	0.02
Administrative	1	2	3	0.01
Security	0	0	1	0.00
Total Staff	5	8	33	0.07

The Fluor report (Fluor Daniel, Inc. 1988) also contains data on the fixed costs incurred by the plant and the labor portion thereof, shown here in Table 7.6. Fluor indicates that variable costs contain no labor component.

TABLE 7.6. Fixed Costs for Operation of a Combined-Cycle Combustion Turbine Plant

<u>Fixed Costs</u>	<u>12 Months Base Load Costs (in thousands of 1988 \$/yr)</u>		
	<u>Phase 1</u>	<u>Phase 2</u>	<u>Phase 3</u>
Operating Labor	116	175	1,165
Maintenance Labor	116	175	525
Maintenance Material	132	263	788
Administrative & Support Labor	58	116	216
Total Fixed Costs:	422	729	2,694
Labor Portion:	69%	64%	71%

7.2.2 Operation Land-Use Impacts

Land-use impacts of operation consist of the area used by the site and the impacts associated with the production and delivery of natural gas. The impacts of the site are discussed above, and there are no data on the impacts of the production and delivery of natural gas.

8.0 GEO THERMAL

A summary of the impacts of the construction and operation of geothermal systems on employment and land use is shown in Table 8.1. Sections 8.1 and 8.2 provide detailed discussions of how these impacts were determined.

TABLE 8.1. Resource Summary for Geothermal Systems

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	4.1	0.2
Operation	0.3	NQ

(a) Construction is in employee years per megawatt capacity; operation is in employees per year per megawatt capacity.

(b) Construction is in total acres disturbed per megawatt capacity; operation is in acres disturbed per year per megawatt capacity.

NA = Not quantified.

8.1 CONSTRUCTION

The construction schedule for geothermal plants, the employment schedule, and the land-use impacts during construction are discussed below.

8.1.1 Schedule and/or Duration

Geothermal power is developed in incremental stages, so that capacity is brought on-line throughout a long construction period. A number of sources provide data on construction duration. Note non-construction downtime (four winter months per year) is included in the duration estimate (i.e., a project taking three 8-month seasons to build has a duration of 36 months).

8.1.2 Direct Employment Schedule

The Worldwatch Institute Report (Flavin and Lenssen 1990) estimates that geothermal power results in 112 jobs per 1,000 gigawatt-hours per year. This is an annual average, including both construction and operation.

TABLE 8.2. Construction Duration for Geothermal Systems

<u>Source</u>	<u>Capacity (MW)</u>	<u>Type^(a)</u>	<u>Duration (months)</u>	<u>Months per MW</u>
OTA 1985	53	Flash	36-60	0.7-1.1
OTA 1985	70	Binary	36-60	0.5-0.9
OTA 1985	10	Binary	12	1.2
USDA 1979	100	NA	84-120	0.8-1.2
USDA 1979	1000	NA	120-240	0.1-0.2
Geyer 1988	100	NA	36-60	0.4-0.6
NWPPC 1989h	50	NA	36	0.7
NWPPC 1989h	25	NA	28	1.1
NWPPC 1989h	10	NA	16	1.6
CEC 1983	2246	NA	146	0.1
CEC 1983	3000	NA	192	0.1
BPA 1985	1	Binary	4	4
BPA 1985	8.4	Binary	84	10
BPA 1985	11.6	Flash	72	6.2
BPA 1985	10.7	Binary	72	6.7
BPA 1985	5.6	NA	48	8.6
Average	419	--	71	0.17

NA = Information not available.

(a) A binary geothermal system is a two-phase system that transfers lower temperature geothermal heat to a secondary heat transfer fluid. A flash system converts higher temperature (150 to 280°C) geothermally heated water to steam for electricity production.

A variety of sources contain data on the construction employment requirements of geothermal plants. Estimates range from 1.2 to 6.9 employee years per MW capacity. An average value of 4.1 employee years per MW capacity will be used. The various estimates are described below.

A report issued by the U.S. Department of Agriculture (USDA 1979) uses data derived from the Geysers experience in California. This report states that a 1,000-MW facility is assumed to take 10 to 20 years to develop and average 150 to 300 employees in the development stage. These figures provide a range of between 1.4 and 6 employee years per MW capacity.

Geyer (1988) estimates that during the two to three 8-month construction seasons, 70 to 100 workers may be on the job, with 20 more elsewhere. For the 100-MW plant, calculations render figures ranging from 1.2 to 2.4 employee years per MW capacity.

ECO Northwest et al. (1986) reports that the employment impacts of building a 10-MW geothermal facility would be insignificant.

A study done by the California Energy Commission (1983) estimates a 2,246-MW facility would require 15,141 construction employee years (6.7 per MW), while a 3,000-MW facility would require 20,706 employee years (6.9 per MW).

8.1.3 Construction Land-Use Impacts

Construction land-use impacts consist of the area required to site the plant. The following two sources present a large range of acreage requirements, stating that the range is much narrower if restricted to just the plant site. While it is important to include areas beyond the plant site (such as roads and transmission lines), no data on these areas have been located for the other resources. For this reason, an estimate of 0.2 acres per MW capacity has been chosen as best representing the data below.

The ECO Northwest report (ECO Northwest et al. 1986) states that the land-use impacts would be insignificant.

Geyer (1988) estimates a 100-MW plant would require development of 160 acres of a 1,280-acre area, or 1.6 acres per MW capacity out of 128 acres per MW capacity. The land-use would consist of

- 20 acres for plant site
- 60 acres for roads and pipelines
- 60 acres for 20 three-acre drill pads
- 10 to 20 acres for power-line right-of-way.

In a report on new electric power technologies, the OTA (1985) presented estimates of land-use requirements for three types of geothermal plants (see Table 8.3).

TABLE 8.3. Acreage Requirements for Geothermal Plants

<u>Plant Type</u>	<u>Capacity (MW)</u>	<u>Land Use (acres)</u>	<u>Acres per MW</u>
Flash	53	8 - 20	0.15 - 0.38
Binary	70	8 - 20	0.11 - 0.29
Binary	10	1 - 3	0.10 - 0.30
Average	44.3	5.7 - 14	0.12 - 0.32

8.2 OPERATION

The employment impacts resulting from operation of a geothermal plant are discussed below.

8.2.1 Direct Employment

A USDA study (1979) estimates a 100-MW plant requires 10 people for plant operation, well maintenance, and pipeline maintenance, while steam production will require one drilling rig with a 20-man complement. The USDA study also estimates a 500-MW facility would require 100 to 150 employees, and a 1,000-MW facility would require 200 to 300 employees. The California Energy Commission (1983) estimates 15,200 O&M employee-years for a 2,246-MW facility (6.8 per MW), and 15,660 for a 3,000-MW facility (5.2 per MW). Assuming a 20-year life provides a range of estimates from 0.26 to 0.34 operators per MW per year, averaging 0.28. These data are summarized below.

TABLE 8.4. Employment Levels for Geothermal Plants

<u>Plant Capacity (MW)</u>	<u>Number of Employees</u>	<u>Employees per MW per yr</u>
100	30	0.3
500	100-150	0.2-0.3
1,000	200-300	0.2-0.3
2,246	760	0.34
3,000	783	0.26
Average: 1,369	375	0.26-0.30

As a note of caution, Geyer (1988) states that the jobs-per-megawatt ratio varies with total plant size, because operating crews do not grow proportionally. The report describes existing facilities of 25 to 80 MW capacity as needing 25 to 35 permanent staff to operate. A 10-MW plant requires 20 people, with an additional 10 in the well field. The skill mix is as follows:

- 9 operators
- 4 maintenance mechanics
- 2 engineers
- 2 clerks
- 1 secretary
- 1 plant supervisor
- 2 to 5 temporary laborers
- 8 permanent well-field employees
- 2 temporary well-field employees
- contract drillers.

The ECO Northwest study (ECO Northwest et al. 1986) states there would be no impact from the operations employment of a 10-MW geothermal plant.

8.2.2 Operation Land-Use Impacts

Land-use impacts are discussed in Section 8.1.3.

9.0 HYDRO

A summary of the impacts of the construction and operation of hydro electric facilities on employment and land use is shown in Table 9.1. Sections 9.1 and 9.2 provide detailed discussions of how these impacts were determined. The hydro designations in the table (Hydro 1, 2, 3, and 4) refer to generic cost categories that are described in the 1990 Bonneville Resource Program (BPA 1990). New Hydro 1 is the least expensive per unit of capacity; New Hydro 4 is the most expensive. These categories reflect generic groups of hydro facilities and not specific projects.

TABLE 9.1. Resource Summary for Hydro Electric Facilities

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	9.3	NQ
Operation	0.3	NQ
Hydro Efficiency Improvements:		
	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	4.9	0
Operation	0.0	0
New Hydro 1:		
	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	8.3	NQ
Operation	0.2	NQ
New Hydro 2:		
	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	10.4	NQ
Operation	0.2	NQ
New Hydro 3:		
	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	14.3	NQ
Operation	0.3	NQ
New Hydro 4:		
	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	17.3	NQ
Operation	0.4	NQ

-
- (a) Construction is in employee years per megawatt capacity;
operation is in employees per year per megawatt capacity.
(b) Construction is in total acres disturbed per megawatt capacity;
operation is in acres disturbed per year per megawatt capacity.
NQ = Not quantified.

9.1 CONSTRUCTION

The construction schedule for hydro electric facilities, the employment schedule, and the land-use impacts during construction are discussed below.

9.1.1 Schedule and/or Duration

Numerous sources present scheduling data on construction of hydro electric facilities. A summary of the data is presented below in Table 9.2.

TABLE 9.2. Construction Duration for Hydro Electric Facilities

<u>Source</u>	<u>Capacity (MW)</u>	<u>Duration (months)</u>	<u>Months per MW</u>
BPA 1985	1	24	24
BPA 1990	10	36	3.6
NWPPC 1989a	190	36	0.19
NWPPC 1989a	290	36	0.12
NWPPC 1989a	340	36	0.11
NWPPC 1989a	240	36	0.15

9.1.2 Direct Employment Schedule

The only specific employment data located were found in a Charles River Associates report (1984), which cites a figure of 5 to 15 employee years per one million 1983 dollars spent on construction. The large range is caused by differences in the sizes of hydro plants. Using the GNP price deflator and assuming no changes in construction labor productivity, these figures calculate a range of 4.2 to 12.5 employee years per one million 1989 dollars in construction costs. The midpoint of this range, 8.4 employee years per million dollars in capital costs, will be used in this analysis.

Capital cost estimates per MW capacity (NWPPC 1989a) and estimates for efficiency improvements (BPA 1985) for new hydro facilities can be used in conjunction with the employee years estimate chosen above to calculate estimates of construction employment per MW of generation capacity. Table 9.3 presents these concepts (capital costs inflated to 1989 \$ using the GNP price deflator).

TABLE 9.3. Capital Costs and Employment Levels for Construction of Hydro Facilities

New Hydro Facilities:

<u>Resource</u>	<u>Capacity (MW)</u>	<u>Capital Costs (1989 \$/kW)</u>	<u>Employee Years per MW Capacity (years/MW)</u>
New Hydro 1	190	985	8.3
New Hydro 2	290	1,240	10.4
New Hydro 3	340	1,700	14.3
New Hydro 4	240	2,060	17.3
Average:	265	1,496	12.6

Efficiency Improvements:

<u>Resource^(a)</u>	<u>Capacity (MW)</u>	<u>Capital Costs (1989 \$/kW)</u>	<u>Employee Years per MW Capacity (years/MW)</u>
Kaplan Governor	0.5	91	0.8
Francis Runner	1.0	568	4.8
Kaplan Runner	1.0	1,079	9.1
Average:	0.8	579	4.9

(a) Kaplan governors and Francis and Kaplan runners are mechanical improvements that increase hydro facility efficiency.

This analysis estimates an average of 12.6 employee years per MW of new hydro capacity, and 4.9 employee years per MW of capacity from hydro efficiency improvements.

These same capital cost figures were adopted by Bonneville in the 1990 Resource Program (BPA 1990).

9.1.3 Construction Land-Use Impacts

While improvements in the efficiency of existing hydro facilities would not result in any land-use impacts, new hydro facilities could easily result in extensive land-use impacts. Impacts would be expected due to flooding and potential changes in river flow patterns. The land-use impacts from new hydro facilities will vary considerably according to the specifics of a particular project. The Department of Energy's Energy Technology Characterizations

Handbook (DOE 1983) describes a 357-MW-capacity run-of-river (i.e., no storage capacity) hydropower dam as requiring 397 acres, or 1.11 acres per MW capacity. This area consists only of the dam. However, it should be noted that this figure does not include any area flooded by the dam. Because of the sensitivity of the land-use impact to the specifics of the project, no further attempt to quantify the land-use impacts will be undertaken.

9.2 OPERATION

The employment impacts resulting from operation of a hydro facility are discussed below.

9.2.1 Direct Employment

Hydropower efficiency improvements are assumed to require no additional operations or maintenance employees.

DOE's Technology Characterizations Handbook (DOE 1983) describes a 357-MW-capacity run-of-river hydropower dam as requiring 16.8 employees. This calculates to 0.05 employees per MW capacity.

Another method of determining the operations labor requirements of a new hydropower facility is to back it out of an estimate of the fixed O&M expenditures per MW capacity. Bonneville's 1990 Resource Program Technical Report (BPA 1990) estimates a new small hydro facility as having annual O&M expenditures of \$33,579 per MW capacity, in 1989 dollars. This is an average of the four new hydropower alternatives. The average labor fraction of O&M expenditures over six technologies (pulverized coal, AFBC, IGCC, CCCT, SCCT, and nuclear) is 56% (see the Appendix for supporting data and documentation). This implies O&M labor expenditures of \$18,804 per MW capacity, in 1989 dollars. Assuming an average O&M worker salary of \$37,492 (the pulverized coal figure cited in BPA 1987) results in 0.50 O&M employees per MW capacity. The figure of 0.28 O&M employees per MW capacity, which is the average of this estimate and the 0.05 developed from DOE 1983, will be used for the overall average. Estimates for each of the four alternatives are shown in Table 9.4.

TABLE 9.4. Labor Requirements for Hydro Facility Operation

<u>Resource</u>	<u>Capacity (MW)</u>	<u>Fixed O&M (1989 \$/kW)</u>	<u>Employees per MW</u>	<u>Average Employees per MW ^(a)</u>
New Hydro 1	10	22	0.33	0.19
New Hydro 2	10	28	0.42	0.24
New Hydro 3	10	39	0.58	0.32
New Hydro 4	10	46	0.69	0.37
Average	10	33.8	0.50	0.28

(a) After averaging estimate for each hydro package and 0.05 from DOE 1983.

9.2.2 Operation Land-Use Impacts

Land-use impacts resulting from new hydro facilities are discussed in Section 9.1.3.

10.0 SOLAR

A summary of the impacts of the construction and operation of solar energy systems on employment and land use is shown in Table 10.1. Sections 10.1 and 10.2 provide detailed discussions of how these impacts were determined.

TABLE 10.1. Resource Summary for Solar Energy Systems

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	19.6	3.6
Operation	0.4	0

- (a) Construction is in employee years per megawatt capacity; operation is in employees per year per megawatt capacity.
- (b) Construction is in total acres disturbed per megawatt capacity; operation is in acres disturbed per year per megawatt capacity.

10.1 CONSTRUCTION

The construction schedule for solar plants, the employment schedule, and the land-use impacts during construction are discussed below.

10.1.1 Schedule and/or Duration

The report by the Office of Technology Assessment (OTA 1985) estimates a 10-MW central photovoltaic station takes 2 years to build whether it is a flat-plat or concentrator type station. This works out to 0.41 months per MW.

The Northwest Power Planning Council study (NWPPC 1989b) estimates a 80-MW parabolic trough with gas backup takes 1 year to construct, or 0.15 months per MW.

Bonneville (BPA 1985) estimates the duration for construction of a 100-MW facility, both thermal and photovoltaic, to be 32 months, or 0.32 months per MW.

10.1.2 Direct Employment Schedule

A study by DOE (1981) estimates 17.1 employee years per quadrillion Btu for a photovoltaic plant. This figure includes construction and O&M employees. DOE estimates 22.7 employee years per quadrillion Btu for a central thermal plant.

The Worldwatch report (Flavin and Lenssen 1990) estimates that solar thermal electricity generation provides 248 jobs per thousand gigawatt-hours annually. The figure includes both construction and operation.

The Solar Energy Research Institute (SERI 1989) estimated that in 1987, a remote stand-alone 1-kW system cost \$10,660. Within this figure, \$1,500 (14%) was for labor. They also estimated the total cost for a large, installed grid-tied 1-kW system at \$7,000, of which \$1,000 (14%) was for labor. SERI projected that costs for both systems would fall by the year 2000 (as shown in Table 10.2). In 1989 dollars, a grid-tied system would have labor costs of \$1,075,269 per MW capacity (calculated from figures in Table 10.2). Using an average construction worker salary of \$34,496 (See the Appendix) results in 31.2 construction employee years per MW capacity.

DOE's Technology Characterization Handbook (DOE 1983) estimates a 200-MW-capacity solar thermal plant would require 850 to 1,270 construction employees annually, on average, for a 2- to 3-year period. This results in a range of 1,700 to 3,810 employee years, or 8.5 to 19.1 employee years per MW capacity.

TABLE 10.2. Labor Costs for Construction of Solar Generation Systems

	<u>1990</u>	<u>1995</u>	<u>2000</u>
Remote Stand-Alone 1-kW Installed System (1987 \$/kWp ^(a) , DC):			
Labor	\$1,000	\$800	\$500
Total	\$7,550	\$5,350	\$4,050
Labor Percent	13%	15%	12%
Large, Installed, Grid-Tied System (1987\$/kWp, AC):			
Labor	\$800	\$500	\$300
Total	\$5,500	\$2,900	\$2,100
Labor Percent	15%	17%	14%

^(a) Killowatts potential capacity

The same source estimates a solar photovoltaic plant of 109 MW capacity would require 850 construction employees, or 7.8 per megawatt capacity. No construction duration is given, so the same time frame, 2 to 3 years, is assumed. This results in 15.6 to 23.4 employee years per MW capacity.

The five estimates of construction employment requirements given above average to 19.6 employee years per MW capacity.

10.1.3 Construction Land-Use Impacts

A wide number of estimates were located to assess the land-use impacts. Upon consideration, the DOE figure of 3.6 acres per MW was chosen as the most applicable (DOE 1983). The construction land-use impacts consist of the area required by the site.

Baechler, Fickeisen, and Hendrickson (1990) estimate a central station solar plant may require 1,000 to 1,500 acres of land. An ECO Northwest report (ECO Northwest et al. 1986) also predicts 1,000 to 1,500 acres will be required, and calls this impact significant.

The OTA (1985) has estimates for various facilities. These estimates are presented in Table 10.3.

TABLE 10.3. Acreage Requirements for Solar Plants

<u>System Type</u>	<u>Capacity (MW)</u>	<u>Land (acres)</u>	<u>Acres per MW</u>
PV - Flatplate	10	40-370	4-37
PV - Concentrator	10	60-320	6-32
Thermal - Parabolic	0.075	67	893
Thermal - Central Rec.	10.8	700	65
Average	7.7	217-364	242-257
PV Average	10	50-345	5
Thermal Average	5.4	384	479

PV = photovoltaic

DOE's Technology Characterization Handbook (DOE 1983) estimates a 200-MW-capacity solar thermal plant would require 1,000 acres, or 5 acres per MW capacity. These figures average to 3.6 acres per MW.

10.2 OPERATION

The employment impacts resulting from operation of a solar plant are discussed below.

10.2.1 Direct Employment

DOE (1983) estimates a 200-MW-capacity solar thermal plant would require 60 O&M employees, or 0.30 per MW capacity.

Another method of determining the operations labor requirements of a solar facility follows that outlined in Section 10.2.1. Estimates of fixed O&M costs for solar facilities are given in three sources (BPA 1985; DOE 1983; and NWPPC 1989b). These sources estimate that a photovoltaic plant has average O&M costs of \$27,229 in 1989 dollars annually, while a solar thermal plant would have average annual O&M charges of \$33,400 (see the Appendix for the development of these averages). Using an average O&M labor fraction of 0.56 and an average operator salary of \$37,492 (see Section 10.2.1) results in an estimate of 0.41 O&M employees per MW capacity for a solar photovoltaic plant and 0.50 O&M employees per MW for a solar thermal plant. The average of these two estimates is 0.46.

The figure used is the average of the DOE (1983) figure and (0.46). This average amounts to 0.4 employees per MW.

10.2.2 Operation Land-Use Impacts

The land-use impacts are discussed in Section 10.1.3.

11.0 WIND

A summary of the impacts of the construction and operation of wind energy facilities on employment and land use is shown in Table 11.1. Sections 11.1 and 11.2 provide detailed discussions of how these impacts were determined.

TABLE 11.1. Resource Summary for Wind Energy Facilities

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	1.9	5.9
Operation	0.4	NQ

(a) Construction is in employee years per megawatt capacity; operation is in employees per year per megawatt capacity.

(b) Construction is in total acres disturbed per megawatt capacity; operation is in acres disturbed per year per megawatt capacity.

NQ = Not quantified.

11.1 CONSTRUCTION

The construction schedule for wind energy facilities, the employment schedule, and the land-use impacts during construction are discussed below.

11.1.1 Schedule and/or Duration

Several sources present a broad range of scheduling information as summarized in Table 11.2.

11.1.2 Direct Employment Schedule

Cunningham (1986) estimates that construction employment varies on the technology used. Two options of obtaining 80 MW of capacity are examined. The first option uses 455 Flowind 170-kW turbines, while the second uses 31 Boeing MOD-2 2.5-MW turbines. Work-force estimates for these two turbine options are shown in Table 11.3.

TABLE 11.2. Construction Duration for Wind Energy Plants

<u>Capacity (MW)</u>	<u>Construction Duration (months)</u>	<u>Months per MW</u>	<u>Source</u>
0.2	12	60.0	NWPPC 1989G
20	4	0.2	BPA 1985
20	6	0.3	BPA 1985
20	10	0.5	BPA 1985
20	16	0.8	BPA 1985
650	12-24	0.02-0.04	OTA 1985
80	12	0.15	Cunningham 1986
80	24	0.3	Cunningham 1986

TABLE 11.3. Construction Work-Force Requirements for Wind Energy Generators

<u>Turbine Type</u>	<u>Local</u>	<u>Non- Local</u>	<u>Total</u>	<u>Employee Years</u>	<u>Employee Years per MW</u>
FloWind 170 kW	150	25	175	175	2.2
Boeing MOD-2 2.5 MW	43	81	124	248	3.1

ECO Northwest estimates that 25 construction employee-years would be required for a 50-MW facility, or 0.5 employee-years per MW (ECO Northwest et al. 1986).

The average of these three estimates is 1.9 employee years per MW capacity.

The Worldwatch Institute report (Flavin and Lenssen 1990) estimates that wind power generates 542 jobs per thousand gigawatt-hours annually, including construction and operation.

11.1.3 Construction Land-Use Impacts

Siting requirements for wind parks include the land immediately adjacent to each generator and other reserved land needed to ensure proper spacing between the generators. Blair, Jones, and Jones (1986) estimate the land-use impacts for the Boeing MOD-2 and the FloWind 170 described above, as well as

for 259 DAF 6400 vertical-axis turbines (see Table 11.4). The averaged land-use requirement for the three turbine types is 5.9 acres per MW capacity. This land is occupied by turbines, roads, utility lines, and other equipment dedicated to the maintenance and operation of the plant.

In addition, Bonneville has estimated that for every 4.5 to 6.1 acres of land needed for each MW of capacity for a wind generator, another 113.6 to 233.1 acres must be reserved to space the generators.^(a) Most of this additional land in a wind park is available for compatible uses, such as livestock grazing, some types of agriculture, or photovoltaic power production.

TABLE 11.4. Acreage Requirements for Generator Types (acres)

	<u>Boeing MOD-2</u>	<u>Flowind 170</u>	<u>DAF 6400</u>
Permanent:			
Machine Foundations	6	4	2
Accessory Facilities	1	1	1
Access Roads	22	52	42
Total	29	57	45
Total Per-MW Capacity	0.36	0.71	0.56
Disturbed During Construction:			
Clearing for Wind Access	55	60	55
Machine Erection Areas	51	202	115
Total	56	244	119
Total Per-MW Capacity	0.70	3.05	1.49
Total Including Land Partially Obstructed by Guy Wires:			
Total	56	752	617
Total Per-MW Capacity	0.70	9.4	7.7

^(a) Personal communication from Nick Butler, Bonneville Power Administration, December 11, 1991.

11.2 OPERATION

The employment impacts resulting from operation of a wind generator facility are discussed below.

11.2.1 Direct Employment

In addition to the operations employment impacts included in Flavin and Lenssen (1990) and the ones discussed above in Table 11.3, Cunningham (1986) estimates employment impacts for the 80-MW Cape Blanco facility shown in Table 11.5 below.

11.2.2 Operation Land-Use Impacts

The permanently disturbed land requirements are discussed in Section 11.1.3. Blair, Jones, and Jones (1986) also indicate significant potential for noise and visual impacts on residential areas.

TABLE 11.5. Operations Work-Force Requirements for Wind Energy Plants

	<u>Local</u>	<u>Non- Local</u>	<u>Total</u>	Total per MW
FloWind 170 kW	18	2	20	0.25
Boeing MOD-2 2.5 MW	25	25	50	0.62
Average	22	14	35	0.4

12.0 NUCLEAR

A summary of the impacts of the construction and operation of nuclear plants on employment and land-use is shown in Table 12.1. Sections 12.1 and 12.2 provide detailed discussions of how these impacts were determined.

TABLE 12.1. Resource Summary for Nuclear Plants

	<u>Employment^(a)</u>	<u>Land Use^(b)</u>
Construction	1.8	3.5
Operation	0.9	NQ

- (a) Construction is in employee years per megawatt capacity; operation is in employees per year per megawatt capacity.
- (b) Construction is in total acres disturbed per megawatt capacity; operation is in acres disturbed per year per megawatt capacity.
- NQ = Not quantified.

12.1 CONSTRUCTION

The construction schedule for nuclear energy plants, the employment schedule, and the land-use impacts during construction are discussed below.

12.1.1 Schedule and/or Duration

Numerous sources offer figures on construction scheduling. These figures are presented in Table 12.2.

TABLE 12.2. Construction Duration

<u>Capacity (MW)</u>	<u>Duration (months)</u>	<u>Months per MW</u>	<u>Source</u>
2,540	108	0.04	BPA 1985
1,250	60	0.05	NWPPC 1989e
1,240	60	0.05	NWPPC 1989e
1,000	132	0.13	OTA 1985
2,664	120	0.05	Denver Research Inst 1982
2,200	96	0.04	Denver Research Inst 1982

12.1.2 Direct Employment Schedule

The Worldwatch Institute report (Flavin and Lenssen 1990) estimates 100 jobs per thousand gigawatt-hours per year. This figure includes both construction and operation.

The Council on Economic Priorities (1979) estimates the regional employment impacts of nuclear-generated electricity to be 0.22 to 0.51 labor years per GWh. Again, this includes both construction and operation.

Charles River Associates (1984) estimates that nuclear generation produces 29 jobs per million kWh supplied, or 254 jobs per MW capacity. This includes construction and operation over a 30-year period.

The study by Baechler, Fickeisen, and Hendrickson (1990) put the construction force for the 1,250-MW Washington Public Power Supply System Nuclear Plant (WNP)-1 plant at 2,000 to 3,000. This calculates to 1.6 to 2.4 employees per MW.

The Denver Research Institute (1982) provides employment estimates for two nuclear plants. These values are presented in Table 12.3.

TABLE 12.3. Employment Levels During Construction of Nuclear Plants

<u>Plant</u>	<u>Capacity (1,000 MW)</u>	<u>Construction Manhours (thousands)</u>	<u>Employee Years (per MW)</u>	<u>Peak Construction Employment</u>	
				<u>(Total)</u>	<u>(per MW)</u>
Bellefonte	2.66	45,000	8.4	4,350	1.6
San Onofre	2.20	43,023	9.8	3,764	1.7

Using the three sources that have separate construction estimates, an average of 1.6 to 1.9 employee years per MW capacity is obtained. Therefore, 1.8 employee years per MW is used.

12.1.3 Construction Land-Use Impacts

Baechler, Fickeisen, and Hendrickson (1990) estimate the total land area required for a fuel cycle to support a 1,000-MW plant to be 113 acres or 0.11 acres per MW capacity. Only 13 acres is permanently dedicated, while 100 acres is temporarily committed. And 22 acres of the 113 is disturbed during construction. If all three of the Washington Public Power Supply System

nuclear plants - WNP-1, WNP-2, and WNP-3 - were completed, Bonneville estimates indicate that 1.74 acres per MW of capacity would be occupied.^(a)

The Office of Technology Assessment (OTA 1985) estimates a 1,000-MW plant requires 1,000 acres. This calculates to 1 acre per MW capacity.

The Northwest Power Planning Council (NWPPC 1990) has estimates for land requirements for a 1,250-MW capacity light water reactor. These estimates are presented in Table 12.4.

TABLE 12.4. Acreage Requirements for a 1,250-MW Nuclear Plant

	<u>Land (acres)</u>	<u>Acres per MW</u>
Site	200	0.16
Exclusion Area	7,260	5.81
Total	7,460	5.97

Averaging the OTA figure (1 acre per MW) and the NWPPC figure (5.97 acres per MW) gives a value of 3.5 acres per MW. Bonneville's estimate for the Washington nuclear plants falls within this range at 1.74 acres per MW. Because only these plants are under consideration by Bonneville, the 1.74 acres per MW figure will be used.

12.2 OPERATION

The employment and land-use impacts resulting from operation of a nuclear power plant are discussed below.

12.2.1 Direct Employment

Several sources (Flavin and Lenssen 1990; Charles River Associates 1984; and the Council on Economic Priorities 1979) provide estimates of employment for both construction and operation. These are cited in the discussion on construction employment impacts. The International Energy Agency (1989) estimates that labor accounts for 67% of the fixed O&M costs at U.S. nuclear

^(a) Estimates for Washington nuclear plants are taken from site drawings; estimates provided in personal communication from Kristina Rohe, Bonneville Power Administration, to Michael Baechler, Pacific Northwest Laboratory, December 13, 1991.

plants. Using the 67% figure and fixed O&M numbers from Bonneville (BPA 1985) and the NWPPC (1989e), and assuming nuclear operations salaries are the same as pulverized coal operations salaries (see the Appendix), estimates for direct employment are calculated. These calculations are presented in Table 12.5.

TABLE 12.5. Employment Levels Required During Operation of a Nuclear Plant

<u>Capacity (MW)</u>	<u>Fixed O&M (1989 \$/kW/yr)</u>	<u>Labor O&M (1989 \$/MW/yr)</u>	<u>O&M Employment per MW</u>	<u>Source</u>
1,250	60.63	40,622	1.1	NWPPC 1989e
1,240	61.12	40,950	1.1	NWPPC 1989e
2,540	34.38	23,034	0.6	BPA 1985
1,677	47.49	31,821	0.9	Average

12.2.2 Operation Land-Use Impacts

Operations land-use impacts would consist of the land disturbed by fuel mining and processing facilities. No attempt was made to estimate the magnitude of this impact.

13.0 CONSERVATION

Conservation is a fundamentally different option than any of the generating options discussed in the preceding sections. Conservation is obtained by retrofitting existing facilities and constructing new facilities that use energy more efficiently. There is no meaningful construction period aspect of a conservation option, nor is there any facility to operate, nor are there any land-use impacts. The discussion of conservation will therefore consist of a review of the literature on labor costs of various forms of conservation.

Raab (1987) conducted a survey of five weatherization firms in Eugene, Oregon, which accounted for half of the weatherization activity in the greater Eugene area. The average cost of installing floor insulation was \$847 (1989 dollars) for 1,500 square feet, of which 24.2%, or \$205, went to labor. These figures were based on 5,925 installations of floor insulation by the five firms. The report states that other types of insulation have similar cost breakdowns. This report also states that 7.3% of the cost of conservation programs is commission; 2.8 % is bonding and insurance; 12.3% is overhead; and 9.1% is profit. All of these categories could reasonably be expected to contain significant labor components: an individual is most likely earning the commissions, and individuals are providing the bonding and insurance, the overhead is paying for office staff and sales personnel, and the profit is going to the business owner. The 24.2% for labor should therefore be viewed as a lower bound, while an upper bound may be found by assuming that all of each of the above expenses goes to labor. This would give an upper bound of 56%. Splitting the difference gives a reasonable estimate of 40%. Charles River Associates (1984) states that most studies find that slightly less than 50% of the cost of conservation programs goes for labor; therefore, 40% seems a reasonable figure.

Bonneville (BPA 1990) provides estimates of the capital cost per kW for a number of conservation resources (see Table 13.1). A rough estimate of the employment impacts can be obtained by using the 40% labor portion discussed above, along with an estimate of average conservation worker salaries.

TABLE 13.1. Employment Levels for Construction of Various Conservation Resources

<u>Resource</u>	<u>Unit Size (MW)</u>	<u>Capital Cost (1989 \$/kW)</u>	<u>Labor Capital Cost (1989 \$/kW)</u>	<u>Employee Years per MW</u>
Residential Space Heat:				
Existing SF	102	5,938	2,375	77.9
Existing MF	36	5,669	2,268	74.3
New SF	116	6,039	2,416	79.2
New MF	32	6,189	2,476	81.2
New Manufactured	96	4,191	1,676	55.0
Residential Appliances:				
Refrigerators	82	1,428	571	18.7
Freezers	29	1,780	712	23.3
Water Heating	258	1,383	553	18.1
Commercial:				
Exist. Bldgs Disc.	162	2,304	922	30.2
Exist. Bldgs Lost Opp.	149	1,539	616	20.2
New Const Lost Opp.	317	1,493	597	19.6
Industrial:	256	1,673	669	21.9
Agricultural:	35	1,717	687	22.5

SF = single-family

MF = multi-family

Charles River Associates (1984) assumes the average conservation worker earns \$30,500, when adjusted to 1989 dollars.

For comparison, a report by Charles River Associates (1984) provides its own estimate of the employment impacts of conservation. The same report estimates that 2 employee years will be created in the region per 1 million kWh supplied. This figure includes investment and operating costs over 30 years, as well as the decrease in employment due to utilities receiving lower revenues. Converting kWh to MW of capacity provides an estimate of 17.5 employee years per MW capacity, a figure not inconsistent with the more specific values given above.

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APPENDIX

DEVELOPMENT OF ASSUMPTIONS

APPENDIX

DEVELOPMENT OF ASSUMPTIONS

Tables A.1 through A.10 show the assumptions used by the authors in the analyses described in this report to determine impacts in terms of land use and employment as a result of the different energy-generating alternatives under consideration in the Bonneville Power Administration's Draft Resource Program Environmental Impact Statement (BPA 1991).

TABLE A.1. Converting to 1989 Dollars Using the Gross National Product Price Deflator

<u>Year</u>	<u>GNP Price Deflator</u>	<u>Multiplier to Convert to 1989 \$</u>
1970	42.0	3.01
1971	44.4	2.84
1972	46.5	2.72
1973	49.5	2.55
1974	54.0	2.34
1975	59.3	2.13
1976	63.1	2.00
1977	67.3	1.88
1978	72.2	1.75
1979	78.6	1.61
1980	85.7	1.47
1981	94.0	1.34
1982	100.0	1.26
1983	103.9	1.22
1984	107.8	1.17
1985	111.0	1.14
1986	113.8	1.11
1987	117.4	1.08
1988	121.3	1.04
1989	126.3	1.00

TABLE A.2 Salary and Wage Estimates

<u>Source</u>	<u>Technology</u>	<u>Description</u>	<u>Base Year</u>	<u>Annual Salary (Base \$)</u>	<u>Hourly Wage (Base \$)</u>	<u>Annual Salary (1989 \$)</u>
Charles River 1984	Conserv	Installation	1983	\$25,000		\$30,390
Charles River 1984	Conserv	Install-Non-Union	1983	\$27,600		\$33,550
Charles River 1984	Conserv	Install-Union	1983	\$37,500		\$45,585
BPA 1987	Pulv Coal	Non-Supervis	1987	\$34,000		\$36,578
BPA 1987	Pulv Coal	Supervis	1987	\$51,000		\$54,866
Murdock 1979	Coal	Construct	1975	\$14,780	\$7.39	\$31,479
Murdock 1979	Nuclear	Construct	1975	\$14,780	\$7.39	\$31,479
Cunningham 1986	Wind	Operations-F	1984	\$41,600		\$48,739
Cunningham 1986	Wind	Operations-B	1984	\$40,000		\$46,865
Average:						\$39,948

TABLE A.3. Operations Average by Technology

<u>Technology</u>	<u>Description</u>	<u>Annual Salary (1989 \$)</u>
Pulverized Coal	Operation	\$37,492
Wind	Operation	\$47,802

TABLE A.4. Construction Average by Technology

<u>Source</u>	<u>Technology</u>	<u>Description</u>	<u>Base Year</u>	<u>Annual Salary (Base \$)</u>	<u>Hourly Wage (Base \$)</u>	<u>Annual Salary (1989 \$)</u>
Charles River 1984	Conserv	Install	1983	\$25,000		\$30,390
Charles River 1984	Conserv	Install-Non-Union	1983	\$27,600		\$33,550
Charles River 1984	Conserv	Install-Union	1983	\$37,500		\$45,585
Murdock 1979	Coal	Construct	1975	\$14,780	\$7.39	\$31,479
Murdock 1979	Nuclear	Construct	1975	\$14,780	\$7.39	\$31,479
Average:						\$34,496

TABLE A.5. Actual Labor Fraction of O&M

<u>Source</u>	<u>Technology</u>	<u>Labor Percent of Fixed O&M</u>
BPA 1986	IGCC	56.4%
Fluor 1988	CT	71.5%
IEA 1989	Nuclear	67.0%
IEA 1989	COAL	29.0%

TABLE A.6. Development of Labor Fraction of O&M from Fixed O&M and O&M Employees per MW. Calculated average fixed O&M per MW by technology (averages in Table A.7)

Source	Technology	Fixed O&M (Base \$/ MW/yr)	Base Year	Fixed O&M (1989 \$/ MW/yr)
BPA 1985	CT CC	\$1,630	1985	\$1,855
NWPPC 1989a	CT CC	\$5,400	1988	\$5,623
BPA 1985	CT SC	\$390	1985	\$444
NWPPC 1989a	CT SC	\$2,000	1988	\$2,082
DOE 1983	Coal AFBC	\$13,150	1981	\$17,669
NWPPC 1989a	Coal IGCC	\$61,200	1988	\$63,723
DOE 1983	Coal Pulv	\$4,480	1981	\$6,019
BPA 1985	Coal Pulv	\$25,250	1985	\$28,730
BPA 1985	Coal Pulv	\$17,850	1985	\$20,310
BPA 1985	Coal Pulv	\$9,200	1985	\$10,468
NWPPC 1989d	Coal Pulv	\$125,580	1989	\$125,580
NWPPC 1989d	Coal Pulv	\$60,130	1989	\$60,130
NWPPC 1989d	Coal Pulv	\$57,090	1989	\$57,090
NWPPC 1989d	Coal Pulv	\$43,800	1989	\$43,800
NWPPC 1989d	Coal Pulv	\$31,470	1989	\$31,470
NWPPC 1989a	Coal Pulv	\$32,800	1988	\$34,152
NWPPC 1989a	Coal Pulv	\$20,500	1988	\$21,345
NWPPC 1989f	Wood Cogen	\$50,000	1989	\$50,000
BPA 1985	Cogen 1 Wood	\$67,180	1985	\$76,440
BPA 1985	Cogen 2 Wood	\$67,180	1985	\$76,440
BPA 1985	Cogen 3 Wood	\$67,180	1985	\$76,440
BPA 1985	Cogen 4 Wood	\$272,870	1985	\$310,482
BPA 1985	Cogen 5 MSW	\$439,030	1985	\$499,545
BPA 1985	Geo 1	\$123,750	1985	\$140,807
BPA 1985	Geo 2	\$60,710	1985	\$69,078
BPA 1985	Geo 3	\$43,970	1985	\$50,031
BPA 1985	Geo 4	\$47,660	1985	\$54,229
BPA 1985	Geo 5	\$36,430	1985	\$41,451
NWPPC 1989h	Geothermal	\$62,000	1990	\$62,000
DOE 1983	Large Hydro	\$2,495	1981	\$3,352
BPA 1990	New Hydro 1	\$21,000	1988	\$21,866
BPA 1990	New Hydro 2	\$27,000	1988	\$28,113
BPA 1990	New Hydro 3	\$37,000	1988	\$38,525
BPA 1990	New Hydro 4	\$44,000	1988	\$45,814
NWPPC 1989e	Nuclear	\$61,120	1988	\$63,639
NWPPC 1989e	Nuclear	\$60,630	1988	\$63,129
DOE 1983	Solar PV	\$19,266	1981	\$25,886
BPA 1985	Solar PV	\$25,110	1985	\$28,571
DOE 1983	Solar Thermal	\$14,600	1981	\$19,617
BPA 1985	Solar Thermal	\$29,690	1985	\$33,782
NWPPC 1989d	Solar Thermal	\$46,800	1989	\$46,800
BPA 1985	Wind 1 70 kW	\$20,240	1985	\$23,030
BPA 1985	Wind 2 120 kW	\$29,240	1985	\$33,270
BPA 1985	Wind 3 250 kW	\$23,380	1985	\$26,603
BPA 1985	Wind 4 350 kW	\$19,790	1985	\$22,518

TABLE A.7. Average Fixed O&M by Technology (1989 \$/MW)

<u>Technology</u>	<u>Average O&M</u>
CT CC	\$5,623
CT SC	\$2,082
Coal AFBC	\$17,669
Coal IGCC	\$63,723
Coal Pulv	\$39,918
Wood Cogen	\$117,960
Cogen	\$499,545
Geothermal	\$69,600
Large Hydro	\$3,352
New Hydro	\$35,967
Nuclear	\$63,384
Solar PV	\$27,229
Solar Thermal	\$33,400
Wind	\$26,355

TABLE A.8. Average O&M Employees per MW by Technology (averages in Table A.9)

<u>Source</u>	<u>Technology</u>	<u>O&M Employees per MW</u>
DOE 1981	Coal AFBC	0.22
BPA 1987	Coal AFBC	0.58
BPA 1987	Coal IGCC	0.8
DOE 1981	Coal Pul	0.22
BPA 1987	Coal Pul	0.57
BPA 1987	Coal Pul	0.37
BPA 1987	Coal Pul	0.17
CEC 1983	Geothermal	0.13
CEC 1983	Geothermal	0.11
DOE 1981	Large Hydro	0.05
DOE 1981	Nuclear Blg. Wa	0.16
DOE 1981	Nuclear Pr. Wat	0.16
DOE 1981	Solar Thermal	0.3
Cunningham 1986	Wind-Boeing	0.63
Cunningham 1986	Wind-Flo	0.25

TABLE A.9. Average O&M Employees per MW by Technology

<u>Technology</u>	<u>Average O&M Employees/MW</u>
Coal AFBC	0.40
Coal IGCC	0.80
Coal Pul	0.33
Geothermal	0.12
Large Hydro	0.05
Nuclear Blg. W	0.16
Solar Thermal	0.30
Wind-Boeing	0.44

TABLE A.10. Labor Expenditures on O&M, Labor Portion

<u>Technology</u>	<u>Average Fixed O&M</u>	<u>O&M Labor Fraction</u>	<u>O&M Labor Source</u>	<u>O&M Labor Expenditur</u>	<u>O&M Salary</u>	<u>O&M Source</u>	<u>O&M Employees</u>	<u>O&M Source</u>
Coal Pul	\$39,918	0.29	(a)	\$11,576	\$37,492	(b)	0.33	(b)(c)
Coal AFBC	\$17,669	0.43	(d)	\$7,544	\$37,492	(e)	0.40	(b)(c)
Coal IGCC	\$63,723	0.56	(f)	\$35,940	\$37,492	(e)	0.80	(b)
Cogen - Wood	\$117,960	0.56	(g)	\$66,471	\$37,492	(e)	1.77	(h)
Cogen - MSW	\$499,545	0.56	(g)	\$281,494	\$37,492	(e)	7.51	(h)
CT - CCCT	\$5,623	0.72	(i)	\$4,020	\$37,492	(e)	0.11	(h)
CT - SCCT	\$2,082	0.72	(j)	\$1,489	\$37,492	(e)	0.04	(h)
Geothermal	\$69,600	0.56	(g)	\$39,219	\$37,492	(e)	0.12	(k)
New Hydro	\$35,967	0.56	(g)	\$20,267	\$37,492	(e)	0.05	(c)
Solar	\$33,400	0.56	(g)	\$18,821	\$37,492	(e)	0.30	(c)
Wind	\$26,355	0.56	(g)	\$14,851	\$47,802	(l)	0.44	(l)
Nuclear	\$63,384	0.67	(a)	\$42,467	\$37,492	(e)	0.16	(c)
Conservation	\$0	0.00		\$0	\$37,492	(e)	0.00	
Average	\$81,269			\$38,351			1.00	

(a) International Energy Agency 1989

(b) BPA 1987

(c) DOE 1983

(d) Average of pulverized coal and IGCC.

(e) Assumed same as pulverized coal.

(f) BPA 1986

(g) Average of pulverized coal, AFBC, IGCC, CCCT, SCCT, and nuclear.

(h) Calculated as O&M labor expenditures divided by salary.

(i) Fluor Daniel Inc. 1988

(j) Assumed same as CCCT.

(k) California Energy Commission 1983

(l) Cunningham 1986

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