Conf-931165--2

PNL-SA-22853

AIR QUALITY IMPLICATIONS ASSOCIATED WITH THE SELECTION OF POWER PLANTS IN THE PACIFIC NORTHWEST

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November 1993

Presented at the
Pacific Northwest International
Section Annual Meeting
November 7-10, 1993
Victoria, British Columbia, Canada

Work supported by
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Table 1. Resource Program Alternatives

Alternative Name (Resource Emphasized)	Description
Status Quo	Bonneville continues doing business as usual. Bonneville chooses new resources based upon minimizing system total cost, without accounting for environmental externalities.
Base Case	Bonneville includes environmental externalities in calculating total system cost. This is the benchmark case against which other cases are compared.
Conservation	This alternative moves lost opportunity and discretionary conservation resources to the top of the resource stack.
High Conservation	A greater amount of conservation is emphasized than in the previous alternative, reflecting conservation measures that may become cost effective within the planning horizon but that carry additional risk because of their unproven nature.
Coal	One part of this alternative emphasizes conventional coal. Another subpart of this alternative emphasizes clean coal technologies, including fluidized bed and coal gassification.
Nuclear	Nuclear plants WNP-1 and WNP-3, currently mothballed, are completed.
Combustion Turbines	Combustion turbines will be the first resource used to meet load growth.
Renewables	Hydro, solar, wind, and geothermal are moved to the top of the resource stack.
Cogeneration	Cogeneration resources are emphasized first.
Fuel Switching	This alternative includes fuel switching as a Bonneville program.
Imports	This alternative emphasizes the use of long-term firm contracts with California and Canada to supply new energy to the region.

EMISSION INVENTORIES AND POLLUTANT EMISSION RATES

PNL modeled air emissions at four sites representative of environmental features in the region, such as climate, human and wildlife populations, and crop and vegetation diversity. These sites are likely candidates for coal-fired power-plant development. Modeled sites are located in western Washington (Centralia), eastern Washington (Creston), eastern Montana (Colstrip), and northeastern Oregon (Boardman). Distinctions were made in the age and efficiencies of powerplants located at different geographic locations. We assumed that plants are operated in a least-cost manner. The least expensive resources are used first; the greater-cost resources are operated least. Our assumptions about the location of different types of electricity generation, and their emission rates, are listed in Table 2.

TABLE 2. Location, Types, and Emission Rates of Power Generation Facilities.

<table>
<tr><th colspan="2" rowspan="2">Type of Facility</th><th colspan="4">Emission Rates (lbs/mmBtu)</th><th rowspan="2">West WA</th><th rowspan="2">East WA</th><th rowspan="2">East OR</th><th rowspan="2">East MT</th></tr>
<tr><th>NO_x</th><th>SO_2</th><th>TSP</th><th>CO_2</th></tr>
<tr><td rowspan="2">Conventional Coal</td><td>existing</td><td>0.5833[a]</td><td>0.774[a]</td><td>0.030</td><td>205</td><td rowspan="2">✓</td><td rowspan="2">✓</td><td rowspan="2">✓</td><td rowspan="2">✓</td></tr>
<tr><td>new</td><td>0.500</td><td>0.200</td><td>0.030</td><td>205</td></tr>
<tr><td colspan="2">Fluidized Bed Coal</td><td>0.134</td><td>0.080</td><td>0.015</td><td>205</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="2">Gasified Coal Combined Cycle</td><td>0.105</td><td>0.040</td><td>0.0066</td><td>205</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td rowspan="4">Combustion Turbine</td><td>NW existing simple and combined cycle</td><td>0.174</td><td>0.001</td><td>0.0133[a]</td><td>117</td><td rowspan="4">✓</td><td rowspan="4">✓</td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>NW and Canada new combined cycle</td><td>0.174</td><td>0.001</td><td>0.001</td><td>117</td></tr>
<tr><td>California[a] new combined cycle</td><td>0.0275</td><td>0.0006</td><td>0.001</td><td>119</td></tr>
<tr><td>California[a] existing</td><td>0.118</td><td>0.0006</td><td>0.001</td><td>119</td></tr>
<tr><td>Cogeneration</td><td>Natural Gas Fired</td><td>0.175</td><td>0.001</td><td>0.001</td><td>117</td><td>✓</td><td></td><td>✓</td><td></td></tr>
<tr><td colspan="10">✓ indicates that a power plant is located in that location.
[a] These values are taken from CEC 1989.</td></tr>
</table>

Although nuclear and renewable resources (e.g., geothermal, hydro, solar, and wind) were included in Bonneville's mix of resources, evaluation of impacts of emissions from these types of plants was beyond the scope of the analysis. Our emphasis was on air quality impacts of central, fossil fuel powerplants. Residential and commercial emissions impacts were not considered, and impacts from cogeneration applied only to emissions from natural gas-fired power generation, not to emissions from generating heat for industrial applications. Emissions from power generated for use outside Bonneville's service area were also not considered. PNL focused on three years (1991, 2000, and 2010) and estimated seasonally averaged and total average release rates for each combination of pollutant, site, study year, and alternative.

Emission rates summed over all sites for each study year showed increases for all alternatives. Colstrip showed the highest level of emissions in all study years; Creston, showed the lowest. Of the three sites active in 1991, the greatest increase in emission rates would occur at Boardman. In the year 2010, High Conservation, Renewable, and Fuel Switching are projected to have the lowest pollutant emission rates. If the 3 highest emission rates of the Conventional Coal, Status Quo, and Import alternatives were excluded, differences between the highest and lowest rates would be less than 5%. Total regional emissions are shown in Table 3. The greatest and least values for the years 2000 and 2010 are shown in bold.

Table 3. Total Regional Emissions (tons) Resulting From Fossil Fueled Power Plants

Alternatives	NO_x			SO_x			TSP		
	1991	2000	2010	1991	2000	2010	1991	2000	2010
Status Quo	69818	117117	170462	92651	119793	138906	3614	5769	8549
Base Case	69818	117117	159028	92651	119306	133728	3614	5769	7785
Fuel Switching	69818	119097	157534	92651	120522	133798	3614	5873	7785
Nuclear	69818	**114475**	159550	92651	118472	133832	3614	5769	7785
Imports	69818	120974	168968	92651	1218786	136543	3614	6012	8132
Cogeneration	69818	117568	160071	92651	**115414**	**133450**	3614	**5665**	7785
Combustion Turbine	69818	119132	159028	92651	119375	133728	3614	5769	7785
Coal	69818	**137864**	**182174**	92651	**127612**	**144293**	3614	**7090**	**9314**
Clean Coal	69818	120105	162454	92651	121287	137169	3614	6116	8236
High Conservation	69818	118785	**156700**	92651	120279	133659	3614	5838	**7750**
Conservation	69818	116908	159028	92651	119306	133728	3614	5769	7785
Renewables	69818	117777	158507	92651	119723	133798	3614	5804	7785

Ground-Level Air Concentration of NO_x, SO_2, and TSP

The EPA's Industrial Source Complex Short-Term Model (ISCST) (EPA 1986) was used to estimate average and maximum ground-level concentrations for NO_x, SO_2, and TSP. Meteorological data were obtained from the EPA bulletin board's meteorological database and the U.S. Department of Energy's Hanford Site meteorological database. Data included boundary layer mixing height, near-surface winds, atmospheric stability, and surface temperatures. Table 4 shows how combustion turbines and coal-fired powerplants were characterized for modeling purposes.

Table 4. Power Plant Characteristics

Parameter	Coal-Fired	Combustion Turbine
Stack Height	150 m	30 m
Stack Diameter	5 m	3 m
Exhaust Velocity	26 m/s	25 m/s
Effluent Temperature	77°C	156°C

The alternative emphasizing conventional coal was projected to produce above-average pollutant concentrations, in comparison to all other proposed alternatives, at all release sites in both 2000 and 2010. The Clean Coal, Imports and Status Quo alternatives were also projected to produce above-average impacts for some pollutants at one or more sites. The Nuclear, Base Case, Conservation, Renewables, Fuel Switching, and High Conservation alternatives projected production of near- to below-average impacts, except for some above-average NO_X impacts in some years near Centralia. None of the combustion generation comprising the alternatives were found to exceed regulatory limits. However, background concentrations were not taken into account. If cumulative emissions from other sources continue to increase within the region, additional power plant emissions could eventually contribute to violations of air quality standards.

Pollutant Deposition

EPA's MESOPUFF II model (Scire et al. 1984) was used for the pH and wet deposition analyses; ISCST was used for the analysis of dry deposition. Two assumptions reduced the number of necessary simulations:

- normalized release rates for NO_X and SO_2 were assumed; results were converted to estimates for each alternative through postprocessing.
- the model was run for only Centralia and Creston, with Creston results representing characteristics near Boardman and Colstrip.

Non-Acidic Deposition

Wet deposition values in western Washington were comparable to, or greater than, eastern Montana values, even though eastern Montana had a much higher emission rate for particulates. This occurred because the annual precipitation in western Washington was much greater than in eastern Montana.

Wet deposition values tended to be much larger than corresponding dry deposition values. If size distributions for emitted particles that projected higher percentages of larger particles had been assumed, or if greater deposition velocities had been assumed, results for the wet and dry deposition values might have been more comparable.

Acidic Deposition

The pH of the precipitation at each grid point was the sum of acid deposition from emissions and natural acidity of precipitation. As a result of rainfall's natural 5.7 pH, this is the least acidic pH (i.e., the greatest value) that appears in the results (Table 5).

In most cases the low pH of precipitation was projected for summer rather than winter or fall when emissions would be highest. The greater acidity in the summer may be due to greater intensity of precipitation and lower wind speeds that may act to increase concentration of acidic compounds in the air. Even though summer rain is more acidic, the amount of rain during this period is much less than in other seasons; therefore, more acidic compounds are deposited in fall and winter.

Ozone Impacts

A version of the EPA's Reactive Plume Model (RPM-IISS) (Morris et al. 1985) was used to assess ozone concentrations under conditions most favorable for forming ozone. RPM-IISS modeled concentrations in ambient air and in release plumes.

RPM-IISS is a numerical plume model that simulates the interaction of plume dispersion and nonlinear atmospheric photochemistry. RPM-IISS estimates short-term concentrations of primary and secondary pollutants (including ozone) associated with emissions from several fixed sources.

Development of input files, testing and sample runs were conducted by Systems Applications International (SAI). SAI prepared five background atmospheres: clean, typical, and dirty rural environments and typical and dirty urban environments.

TABLE 5. Estimated Average pH of Rainfall at All Sites in 1991 and 2010

Year	Season	Highest or Lowest SO_x Emissions From All Alternatives	Average pH of Rainfall at Maximally Impacted Point							
			Anywhere on Study Grid				Greater Than 200 km From Source			
			West WA	East OR	East WA	East MT	West WA	East OR	East OR	East MT
1991	Fall	---	5.0	5.4	5.7	5.0	5.6	5.6	5.7	5.4
	Winter	---	5.3	5.6	5.7	5.0	5.5	5.7	5.7	5.0
	Spring	---	5.7	5.7	5.7	5.2	5.7	5.7	5.7	5.4
	Summer	---	5.2	4.8	5.7	4.2	5.5	5.4	5.7	4.9
2010	Fall	Low	5.0	5.1	5.3	4.8	5.4	5.2	5.6	5.5
	Fall	Hi	4.9	5.0	5.2	4.7	5.4	5.2	5.6	5.4
	Winter	Low	5.0	5.1	5.3	4.8	5.3	5.2	5.3	4.8
	Winter	Hi	5.0	5.0	5.3	4.7	5.3	5.1	5.3	4.8
	Spring	Low	5.5	5.1	5.4	4.7	5.5	5.4	5.5	5.0
	Spring	Hi	5.1	4.9	5.2	4.7	5.2	5.2	5.4	5.0
	Summer	Low	4.4	4.5	4.7	4.0	5.1	5.3	5.3	4.7
	Summer	Hi	4.4	4.3	4.5	4.1	5.1	5.1	5.2	4.7

Hourly ambient and in-plume ozone concentrations were estimated for a range of NO_X emission rates using each atmosphere. Results indicate that the current and projected levels of pollutant emissions produce maximum concentrations that barely exceed ambient levels. For some sites and study years, the scenarios with the lowest pollutant emission rates produced slightly higher ozone concentrations than the scenarios with the highest emission rates. The type and quantity of pollutants in ambient air appeared to be more important than emission amounts in estimating hourly in-plume ozone concentrations. On average, the analysis indicated that power plant emissions are of secondary importance in ozone formation.

Visibility Attenuation

Visibility attenuation analysis was performed using EPA's PLUVUE II (Seigneur et al. 1984) plume visibility model. PLUVUE is a Gaussian plume model that estimates visibility impairment from single-source emissions of NO_X, SO_X, and TSP. The study did not address visibility attenuation at Class I sites (e.g., national parks, federal wilderness areas) because insufficient information was available on plant dispersal to appropriately address this issue.

Annual average noontime reductions in visible range over the horizon for each combination of site, study year, and alternative were computed by conversion of maximum reduction estimates. Annual average reductions in visual range for all four study sites, in all study years, for all resource alternatives were determined to be less than 1%.

HUMAN HEALTH EFFECTS

PNL estimated the effects on human health from the power plant emissions produced under each alternative for populations within 80 km (50 mi) of release sites. Results from the air quality analysis were combined with 1980 census data to estimate collective exposure to NO_x, SO_x, and TSP at each site. Results were combined with published risk estimates for acute morbidity and mortality to determine the health impact of airborne emissions from the facilities. Human health effects for each site were summed to determine the total impact of each alternative (Table 6).

Impacts were treated as additive; no information was available to determine synergistic or antagonistic effects between various classes of pollutants. Estimates should be treated as relative measures for comparison purposes.

In most cases, the greatest health effects were associated with the conventional coal alternative. Lifetime cancer risks in 2010 (in comparison with 1991) were projected to increase by as much as 80% to 90% (Imports and Conventional Coal alternatives). However, this increase still resulted in a total of less than one statistical lifetime cancer death across the entire region. This estimate is based on documented risk factors; it is quite possible that risks may be greater.

In the alternative with the greatest impacts (conventional coal) annual acute (non-cancer) statistical deaths in this same time period are estimated to increase by about 6, from about 18.5 to 24.5, or about 33%. A similar comparison for acute morbidity results in a maximum increase of 32% to 34% depending on the effect.

Health effects from ozone were based on air quality data and health risk coefficients for ozone. Typical "high" and "low" ambient ozone concentration data were modeled on populations within 80 km of each site to estimate cumulative exposure levels. Ambient ozone levels represented poor-to-moderate air quality, and were independent of pollution from power plants. In-plume concentrations from each site were evaluated for the alternatives with the highest and lowest

TABLE 6. Criteria Pollutant Mortality and Morbidity Effects.

Scenario:	Cumulative Health Risk: Mortality: Cancer (lifetime)	Mortality: Acute (deaths/yr)	Morbidity (Effects per year): Bronchitis	Morbidity: Lower Respiratory Disease	Morbidity: Cough	Morbidity: Colds
Year: 1991 - Impact of Existing Facilities at Beginning of Study Period						
1 - ALL PROGRAMS	0.34	18.44	190.27	91.93	183.86	165.47
Year: 2000 - Impact of New and Existing Facilities						
1 - STATUS QUO	0.46	22.04	228.29	109.84	219.68	197.71
2 - BASE CASE 4	0.46	21.96	227.47	109.43	218.86	196.97
3 - CONSERVATION	0.46	21.96	227.43	109.42	218.84	196.96
4 - CONVENTIONAL COAL	0.54	23.24	241.62	115.78	231.56	208.40
5 - CLEAN COAL	0.48	22.30	231.24	111.14	222.29	200.06
6 - NUCLEAR	0.45	21.79	225.60	108.59	217.18	195.46
7 - COMBUSTION TURBINE	0.47	21.98	227.79	109.54	219.07	197.16
8 - RENEWABLES	0.47	22.01	228.09	109.69	219.38	197.44
9 - COGENERATION	0.45	20.79	215.54	103.58	207.15	186.44
10 - FUEL SWITCHING	0.48	22.15	229.69	110.37	220.73	198.66
11 - HIGH CONSERVATION	0.44	21.38	221.34	106.56	213.11	191.80
12 - IMPORTS	0.54	22.70	236.31	113.09	226.19	203.57
Year: 2010 - Impact of New and Existing Facilities						
1 - STATUS QUO	0.55	23.35	242.99	116.31	232.62	209.36
2 - BASE CASE 4	0.55	23.28	242.33	115.99	231.98	208.78
3 - CONSERVATION	0.55	23.28	242.33	115.99	231.98	208.78
4 - CONVENTIONAL COAL	0.62	24.46	255.12	121.80	243.59	219.23
5 - CLEAN COAL	0.53	23.50	244.07	117.08	234.16	210.75
6 - NUCLEAR	0.56	23.30	242.56	116.08	232.17	208.95
7 - COMBUSTION TURBINE	0.55	23.27	242.13	115.93	231.87	208.68
8 - RENEWABLES	0.55	23.29	242.39	116.04	232.09	208.88
9 - COGENERATION	0.54	23.24	241.65	115.77	231.55	208.39
10 - FUEL SWITCHING	0.54	23.30	242.31	116.08	232.15	208.94
11 - HIGH CONSERVATION	0.55	23.28	242.11	115.95	231.90	208.71
12 - IMPORTS	0.66	23.76	248.91	118.28	236.56	212.90

SOURCE: NOX, SOX, and TSP Health Effects Analysis, RPEIS, Appendix F, Section 2 (BPA 1991) emission levels. Cumulative exposures were calculated assuming that wind was blowing the plume toward the sector with the largest population within 80 km of the site.

Increases in annual mortality rates ranged from 2 to 4 acute deaths per year, depending on assumed ambient pollution levels. Differences in mortality estimates between the alternatives were slight and were comparable in magnitude to those for other pollutants.

WILDLIFE EFFECTS

Air quality analysis results were used to estimate impacts on wildlife populations within 32 km (about 20 miles) of the sites. Mortality estimates were made for mammalian species using population densities reported by local biologists. Mortality estimates for avian species were based on the total number of breeding birds per square mile of each habitat type (Udvardy 1957 and 1958). Waterfowl production estimates were based on data from state biologists and the U.S. Fish and Wildlife Service. Acute mortality risk estimates for humans were used to calculate the deaths per year for wildlife species.

Data predicting acidification of surface waters within a 400-km (about 250 mile) radius of each site were used to evaluate potential impacts of emissions on waterfowl production. The potential impact of metal contamination was obtained from particulate deposition data and reported bioaccumulation rates for metals in edible plant biomass. A hypothetical watershed was used to evaluate the effects of fly ash deposition on terrestrial animals dependent on aquatic vertebrate and invertebrate food sources.

Two metals, arsenic and selenium, pose potential health problems for wildlife that feed on aquatic organisms. Selenium concentrations will probably not reach levels that pose a direct threat to wild animals feeding on aquatic organisms for any alternative. However, selenium concentrations in the water may greatly alter the food resources of wildlife in western Washington and eastern Montana, where concentrations in the water exceed 20 μg/L. The conventional coal alternative may introduce potentially harmful levels of selenium in eastern Oregon's aquatic environment in the year 2010.

The number of projected SO_2- and TSP-induced statistical deaths of birds and mammals living within a 32 km radius of the site was highest for birds and small rodents. Reductions in local populations were under 0.02%. Less than one statistical deer or elk is estimated to be lost in the region.

Ozone exposure predictions also indicate minimal impact to large mammal populations or wild bird communities. Under maximum exposure conditions, one to four additional avian deaths may occur per year.

Lakes and streams in the region, especially along the Cascade Mountain Range, are vulnerable to acid deposition and can receive episodic acidification from rapid snow melt and run-off that can be many more times acidic than precipitation. This episodic acidification can impact waterfowl production because it coincides with two critical waterfowl dependencies on aquatic biota, i.e., the need by female waterfowl to consume aquatic organisms during late winter to meet elevated calcium and protein requirements for egg production and the need for protein-rich aquatic organisms by ducklings during the first 2 months of life for normal development. Acidification in western Washington may cause a reduction in waterfowl production. About 2,000 additional duckling deaths may occur per year. Increased difficulty in foraging may reduce the number and population of species.

EFFECTS ON PLANTS AND CROPS

Air quality analyses for the alternatives were used to estimate the impact of emissions on terrestrial vegetation within plumes projected at the sites. Land-use estimates were divided into crop lands, timber, and pasture. Crop production loss estimates were provided by Agricultural Stabilization and Conservation Service (ASCS) offices in the Washington, Oregon, Idaho, Montana, and North Dakota counties projected to be affected by the plumes. Acreage estimates were adjusted for the percent of the county impacted by pollutant transport or deposition.

Ozone concentration data were analyzed as 7-hour averages because the effects of ozone on vegetation production were given in this form. Maximum 7-hour/day averages for all study years were compared to production response curves for five crops. Crop yield reduction from ozone concentrations was determined by relationships between seasonal 7-h/day mean concentrations and crop yields, which were developed by Heck et al. (1982). The most significant projections were 1% reductions in yield near Boardman in the years 1991 and 2000, and near Creston in 2000 and 2010.

Metal contamination (from metals with known plant toxicity) was calculated using projections of TSP deposition, and published metal concentrations of coal fly ash. The values were used to estimate potential metal deposition to the soil and vegetation.

Plant loss or ecosystem changes from metal deposition were not anticipated for any alternative. Although the impacts could not be quantified, a potential adverse effect on plants was noted for Western Washington, which is susceptible to acid deposition. This deposition can increase the solubility and plant uptake of several metals.

Plant toxicity from SO_2 was estimated by comparing the maximum short-term concentrations projected in the plumes for the years 2000 and 2010. The maximum concentration at any site was about 1.2 ppm. This compared to potential toxic concentrations of 18 to 165 ppm (Moriarty 1983). Based on the difference between maximum projected concentrations and potential toxic concentrations, PNL projected no impact.

The potential toxicity of eight metals was assessed based on the toxicity of the metals in TSP. There were no values during years 2000 and 2010 for which metal concentration factors were projected to exceed reported toxic levels. However, accumulation of metals in the soil could produce concentrations that exceed toxic levels for some plant species.

EXTERNALITY ANALYSIS

The information for this portion of this summary is taken from Englin and Gygi 1992 and Bonneville 1993. The term externalities refers to residual environmental impacts that are not included in the internal costs of building and operating an energy resource. Externalities often represent uncompensated environmental damages although they may also represent benefits. Establishing dollar values for externalities provides an approach for incorporating environmental effects into decisions about resource development and use. Externality costs can then be compared and added with capital and operating costs of resources, allowing for comparisons across generation types.

The "damages-based" approach is used to establish externality costs in this analysis. This approach requires two types of information: the extent or amount of environmental impact, for example a decrease in crop productivity or visibility; and the price or economic value of the good or quality impacted. These two values are multiplied together to determine the total cost or change in social welfare.

Economic values are taken from market prices or estimated using various economic models for valuing nonmarket goods and qualities. For this analysis the economic models were not actually estimated; instead the results of existing studies were used. The validity and applicability of these numbers depends on the types of models used and the way in which the study was conducted. Thus, the values reported here and in Englin 1992 and Bonneville 1993 are not specific to the locations and alternatives under consideration, but are based on studies of similar issues.

A summary of externality values are presented in Table 7. The values that are quantifiable sum to about \$117.5 million in 1991. The values for 2000 amount to a range of from \$145 million to \$157.35, or a 23% to 34% increase. For 2010 the quantifiable values total \$155.25 million to \$162.26 million, or an increase of from 32% to 38% over 1991.

Table 11. Summary of Externality Values (1991 dollars)						
Impact Type	Unit Values	Range of Results			Low and High Alternative	
		1991	2000	2010	Low	High
Human Health Mortality Ozone Mortality Morbidity	 4.4M/ statistical fatality same as above 95.6/lost day	 $80.9M 27.9M 60.5K	 $91.3M - 102M 42.6M 68.2K - 76.2K	 $102M - 107.4M 40.7M 76.2K - 80.3K	 Cogeneration All Cogeneration	 Conventional Coal All Conventional Coal
Visibility	41/mile/person west side of Cascade Mountains 7/mile/person east side of Cascade Mountains	8.6M	11M - 12.6M	12.4M - 14M	Cogeneration, Nuclear, and Clean Coal	Conventional Coal
Crops Hay Wheat	 89.26 ton 4.45 bushel	 14.7K 61.4K	 same same	 same same	All	All
Fish and Wildlife	Not Quantifiable					
Forests and Plants	Not Quantifiable					

CONCLUSIONS

If electricity load in the Pacific Northwest grows at a high rate (1.8% per year) over the next 20 years, generating plants built to meet the load will result in significant increases in air SO_x, NO_x, and TSP. The precise magnitude of this increase will depend on the types of power plants built, their location, and their relationship to the operation of existing powerplants. However, from a regional perspective, these variables are of secondary importance when considered along with load growth. Although the alternative emphasizing the development of conventional coal-fired generation consistently produced the greatest air quality impacts, this study found the differences between the alternatives with the greatest and least emission varies from 15% to 20%. At the assumed high load growth almost all generation resources are required in almost all alternatives 20 years in the future. Though it is difficult to differentiate between the alternatives, it is clear that power generation, and its impacts, will be a central environmental issue confronting the Northwest over the next 20 years.

The external cost of producing electricity is an important consideration in choosing technologies and programs to supply the region's power. This study found similar costs associated with the alternatives under consideration. However, more specific proposals can result in more refined estimates of costs, in terms of both economic values and estimates of physical impacts.

Finally, the complexity of estimating environmental effects of energy programs should be noted. Many studies have relied on averaging techniques in which conservation activities are assumed to affect all electricity generation equally. This study suggests that care must be taken in determining the mix of generation technologies supplying the electricity to be conserved and the timing of the conservation activities. Both are very important in determining which resources are offset.

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