WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Final Cost-Benefit Analysis
and
Analysis of Least Burdensome Alternatives
for
Revision of Chapter 173-434 WAC,

Solid Waste Incinerator Facilities

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Introduction:

The documents contained in the appendices of this document represent the final cost-benefit analysis, and the least burdensome analysis, of the amendments to Chapter 173-434 WAC, Solid Waste Incinerator Facilities. The document in Appendix 1 is the draft cost-benefit analysis, and the least burdensome analysis, prepared for the rule amendments proposed on June 13, 2003. Based on comments received during the comment period, revisions were made to the proposed rule language. Ecology determined that the revisions relating to the cement manufacturing industry needed further economic analysis. This analysis is contained in the document in Appendix 2, and supplements the analysis in the original cost-benefit analysis.

Determinations:

The draft cost-benefit analysis and the least burdensome alternatives analysis contained in the document in Appendix 1 demonstrate that the proposed rule language has net benefits that exceeded costs, and that it was the least burdensome alternative. The analysis described in the document in Appendix 2 only addresses rule amendments impacting the cement manufacturing industry. This analysis demonstrates that the revised rule language has net benefits that exceed the costs and are the least burdensome alternatives.

The analyses described in Appendix 1 and 2, combined, provide Ecology with information to make the determination that the amendments to Chapter 173-434 WAC have net benefits that exceed the costs and are the least burdensome alternatives.

Appendix 1: Draft Cost/Benefit Analysis
Appendix 2: Supplemental memorandum addressing only the amendments impacting the cement manufacturing industry

Appendix 1:

Draft Cost/Benefit Analysis

Draft Cost / Benefit Analysis

For

Revision of Chapter 173-434 WAC

Solid Waste Incinerator Facilities

June 10, 2003

03-02-011

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Cost/Benefit Analysis of Chapter 173-434 WAC

Draft revisions to Chapter 173-434 WAC, Solid Waste Incinerator Facilities.

Introduction:

The Washington Administrative Procedures Act requires that significant legislative rules be evaluated to determine whether the probable benefits of a proposed rulemaking action exceed its probable costs, taking into account both quantitative and qualitative information and analysis (RCW 34.05.328(1)(c)). This report provides that documentation for the above cited rulemaking proposal.

Summary:

The probable benefits exceed the probable costs associated with the proposed changes to Chapter 173-434 WAC. The probable costs associated with the proposed changes are related to the added expense of testing for metals at approximately $100,000 per year. The probable benefits are from several areas, both quantitative and qualitative. The reduced limits on carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen oxides (NOx) create value to the citizens of Washington in excess of $1.2 million dollars. The restoration of 28 employment positions creates a payroll in excess of $1.4 million. With the multiplier effect this increases the economic benefit to the residents of Tacoma and Pierce County to $2 million. The exemption of creosote will create an avoidance savings to landfills in a range of $31,000 to $10 million, with the lower range most likely.

Affected facilities include those currently subject to Chapter 173-434 WAC, and those that burn more than 12 tons per day of creosote-treated wood. The three affected facilities in Washington are the Tacoma Steam Plant in Tacoma, the Kimberly-Clark plant in Everett, and the Waste to Energy facility in Spokane. The Waste to Energy facility in Spokane, which was in existence before the EPA regulations became effective, is not subject to the amended regulation. The current proposed draft language is to change the operational standards from what would be a time and temperature standard to an emission standard. Ecology is proposing that the federal standards found in 40 CFR part 60, Subpart Eb be put in place for solid waste incinerators in the current WAC. The new standard has limits for cadmium, lead, mercury, dioxin, NOx, CO, particulate matter (PM), opacity, SO_2, and hydrogen chloride (HCL), while the current WAC regulates PM, opacity, SO_2, and HCL. A side by side analysis is shown later in the endnotes of this report.[1] It affects any solid waste incinerator that does intend to burn 12 tons or more under the federal regulations 40 CFR part 60, Subpart Eb as if they were burning over 250 tons of solid waste under current regulation. It strengthens the prevention of air pollution and its many components by adding additional pollutant limits. The proposed amendments will impose stricter emission limits on the Tacoma Steam Plant.

The proposed WAC amendments will eliminate overlapping and redundant regulations for the Kimberly-Clark plant by deleting requirements for burning over 12 tons of creosote-treated wood under Chapter 173-434 WAC. Emissions from the burning of creosote-treated wood will continue to be regulated through limits set on sulfur emissions by Kimberly-

Clark's annual operating permit. Cement kilns will continue to operate with no change to their status.[2]

Background information:

Solid waste incinerators in Washington State are regulated by Chapter 173-434 WAC, Solid Waste Incinerator Facilities. This WAC establishes emission standards, design requirements, and performance standards for these facilities. It applies to facilities that incinerate more than 12 tons of solid waste per day. There are currently three facilities in Washington that burn more than 12 tons per day of municipal solid waste (MSW).[3] They are located in Tacoma, Everett, and Spokane. Regulations for the Tacoma and Spokane facilities are enforced by the Puget Sound Clean Air Agency (PSCAA) and the Spokane County Air Pollution Control Authority (SCAPCA). The Department of Ecology regulates the Everett facility because it is a pulp mill.

Solid waste incinerators are a source of air pollutants such as dioxin, mercury, and sulfur dioxide.

The proposed regulatory revisions:

The proposed amendments replace design and operation requirements for solid waste incinerator facilities with emission limits. This means that, instead of regulating a facility based on the way it was built and how it operates, agencies would regulate it based on how much air pollution it emits. Ecology believes this is a more effective and practical way to manage solid waste incinerator facilities because it limits emissions of air pollutants, while allowing facilities to have more flexibility in the way they operate. This represents a change from a more prescriptive to a more performance-based approach. This amendment would also establish limits for some substances not addressed in current regulations. The proposed amendments do not cover the burning of creosote-treated wood because the substances emitted by this type of burning are addressed by other regulations. This exemption eliminates redundancies in the regulations.

Affected businesses:

There are currently three active solid waste incinerators in the state of Washington. Two incinerators are <u>municipally</u> owned and are <u>non-profit</u> in nature. One is located in Spokane, WA and the other is located in Tacoma, WA. They are under SIC # 4911 or NAIC #221112. The exclusion of creosote-treated wood will affect Kimberly Clark (SIC #2621) of Everett, WA by allowing it to be exempt, because of the railroad ties it burns, from Chapter 173-434 WAC.

This report is concentrating on the economic factors that are affected by this revision of Chapter 173-434 WAC. No change is proposed to the incinerator in Spokane due to the fact that it is already constructed, is complying with the current applicable federal regulations and Chapter 173-434 WAC, and will continue to operate under this status. The Tacoma Steam Plant No. 2 is the incinerator that will have the choice to operate under alternative operational regulations. It is the emphasis of this document.

Analysis of least burdensome alternatives:

The state of Washington has reviewed the proposed change with the parties involved and through public meetings, to determine what is achievable and feasible to all involved. There have been several analyses of alternatives and modifications over the last twenty years and substantial investments made in trying several different alternatives. After several years of review and attempts to implement several different alternatives by this facility, it has been determined that the proposed amendment is the least burdensome that is currently available to the Tacoma Steam Plant No.2.

Background information on the two MSW incinerators:

The major difference between these two incinerators is that Spokane is a "water wall" style mass burner[4] and Tacoma has two Bubbling Fluidized Bed style burners.[5] It is because Tacoma has this type of burner that it is difficult to achieve the current Chapter 173-434 WAC requirements (what will be referred to as the present status for this analysis). Under the proposed changes, it is a feasible choice for this plant to be able to operate and achieve compliance with a certain economy of scale.

Tacoma Steam Plant present status:

For economic reasons, the City of Tacoma shut down the Tacoma Steam Plant in December 2001. One of the reasons for the closure of the waste-to-energy facility is that the City has not obtained the regulatory permits necessary to operate the plant. Without the permits, the City also cannot complete much-needed upgrades to improve operating efficiency. This facility has difficulty maintaining the time and temperature requirements of the current regulations because this style of incinerator runs at lower temperatures for longer periods of time compared to the requirements of Chapter 173-434-160(a) WAC. When this facility raises its operating temperature, the formation of "clinkers" occurs, causing fouling problems, damage to the incinerator floor, premature shutdown of the incinerator, and an increase in NOx emissions. Some of these "clinkers" can reach the size of a small car and perhaps as much as a ton in weight. They require removal by hand and cause considerable disruption of operation and expense. In reviewing other plants of this design, bed temperature was the major parameter that had a measurable impact on emissions and efficiency.[6]

The state of the power market and the economic downturn also affected the facility's shutdown. The power market during the height of the energy crisis rose from $25 per megawatt hour to, in some cases, $1,500 per megawatt hour. Currently, the price of electricity is in the range of $22-$25 per MWH.[7] The average cost reported for this plant under the current mix of fuels and overhead is in the low $50 per MWH range. The ideal fuel cost would be zero to a payment for a tipage arrangement. This can occur with industrial waste and tear off materials with a high BTU value. It appears that even with the proposed WAC change, this plant will not be feasible to operate with the current fuel mix along with the current price of electricity. With both furnaces in operation and a high average price per MWH, as in the year 2000 this facility recorded a loss of approximately $370,000. If the current prices held and the plant operated at an average output as in the past, it would incur a loss similar to the year 2000 results or more. For this plant to meet the current WAC standards it would require a major retrofit. The direct compliance costs for the plant to update its economizers are in the range of $1,200,000 to $1,600,000.[8]

OPERATING EXPENSES:

Waste-to-Energy Plant	
Year 2000	Year 1999
$7,282,625	$6,349,711

The City lost roughly $370,000 in 2000 versus $7,282,625 in operating expenses. Estimated losses for 2001 are $1.8 million. Considering the financial issues, the City agreed with its private business partner, NRG Energy, that they cannot sustain the facility in the short-term. However, the City stated it will retain nine employees to actively pursue permitting options and keep the plant staffed at minimum levels. This creates operating expenses for personnel to mothball the plant until it is feasible to operate, keeping it in a "ready" state of condition. The other aspect of this shutdown is the diversion of Municipal Solid Waste (MSW), currently being landfilled at additional expense, from this Tacoma facility. As of January 1, 2003 this facility reduced its total employee figure to three.

"We plan to bring the Steam Plant back online as soon as we possibly can," said Karen Larkin, assistant director of Public Works/Environmental Services. *"Both the City and NRG believe strongly in the benefits the Steam Plant brings to the community, on both the environmental and economical fronts."*

The waste recovery process is relatively straightforward: Waste materials are brought to a sorting facility where they are processed and packed for shipment to the power plant. Recyclable materials, such as ferrous metals, non-ferrous metals, soil, and glass are recovered and recycled before being sold to local businesses. The remaining combustible materials, or RDF, along with a mix of wood waste and coal, are used as fuel to fire boilers that generate steam to produce electricity.

Tacoma Steam Plant proposed change:

This is a voluntary acceptance of the proposed change to Chapter 173-434 WAC. The plant operators' believe this change will help them comply with the federal standards of 40 CFR 60 subpart Eb, versus the current time and temperature requirements. The proposed WAC change allows this plant to phase in the new standards over a 23-month period. The purpose is the same as found in the federal language of 40 CFR 60 subpart Eb, to allow this facility time to retrofit one boiler at a time and learn how to achieve the lower standards for dioxins that are required by the end of the transition period. The addition of several carbon injectors[9] may be required to achieve a larger margin from maximum permitted levels of dioxin and mercury. The expense will be less than $500,000.

This plant will retrofit their economizers[10] to improve the efficiency of the system in either case. The Tacoma Steam plant does not appear to be able to operate at a profitable level under current fuel mix and current electricity prices regardless of this proposed change. It is the understanding that this plant will apply for a change in fuel mix once this proposed change takes effect. This aspect has no relationship to the proposed changes in Chapter 173-434 WAC and will not be discussed further in this paper. This paper will not calculate or estimate the power market or this plant's fuel mix and current cost structure in-depth. The main point is that the proposed change will allow the facility an opportunity to operate versus the inability to operate.

Characteristics of the Tacoma facility:[11]

A study of the Tacoma plant completed in 1998 provides a good description of details and costs of the plant and is included in the footnotes. Please refer to the enclosed portion of the report in full, along with the Spokane facility found later in this paper.

Background on Spokane facility:[12]

This facility is currently constructed and is operating under Chapter 173-434 WAC, and will continue to operate under Chapter 173-434 WAC. Even when the proposed changes to the WAC occur, it would not be required to operate under 40 CFR 60 subpart Eb unless voluntarily or unless a modification is made to the facility that would trigger the application of the proposed changes. This facility has indicated an interest in accepting this proposal to operate. It reduces duplicate filing requirements, reporting differences, and testing procedures of current reports made to the federal government and the state of Washington.

What is the employment profile of businesses affected by the proposed regulation?

The Tacoma facility reduced its staff to three people on January 1, 2003. There are 28 people employed at this facility when in full operation. It is a subsidiary of the city of Tacoma. The city of Tacoma has 3,449 employees.

The Spokane facility currently is in full operation and employs 37 people through Wheelabrator Corporation and 10 additional people through ancillary services. The city of Spokane has 2,218 full-time equivalent employees.

What are the costs for businesses affected by the proposed regulation?

The voluntary capital cost to the Tacoma facility to comply with the proposed rule is insignificant as the cost of the economizers will occur under either option. There should be a minor reduction in costs due to more standardized reporting requirements of the proposed regulation by matching federal reporting regulations. There will be an increase in the cost of testing for the new toxic standards, such as mercury, that will add an expense of approximately $100,000 per year.

There is no cost to the Spokane facility, as it is currently exempt from this proposed regulation change. Should this facility decide to operate under the proposed changes, they should see a reduced burden on reporting. If this facility accepts the new standards then they should see the same increase in expenses as Tacoma for the additional tests.

Do the costs imposed by the proposed rule exceed benefits?

When calculating the cost of proposed amendments to existing regulations, it is very important to separate out and ignore the cost of the current regulations. While important to the regulated parties, the costs of complying with the current requirements are not relevant to this analysis. The only cost issue for the analysis is how much more or less businesses will pay to comply with the amended rule. In this proposed amendment, the cost should be less than the benefits as the current regulations do not allow the Tacoma facility to operate. Please note that under the current economic conditions for the price of electricity and this facility's current fuel mix; it currently may not be feasible to operate under the proposed regulation.

The benefits under this proposed WAC change are both quantitative and qualitative in nature.

The benefits under the quantitative aspect are:

1) When in the Tacoma plant is in full operation, the facility employs 28 full-time employees with an approximate payroll of $1,400,000.[13] Given a multiplier affect of 1.49[14] to the local economy of Tacoma, Washington, it creates an economic effect of $2,086,000 per year.

2) The reduction of emission limits in certain releases of dioxins, carbons, mercury, particulate matter, cadmium, lead, SO_2, HCL, NOx, and CO all have a benefit to citizens of Tacoma, Washington.

The new limits on metals emissions do not currently have an easily assignable value. The reduction of maximum limits for the following SO_2, NOx, and CO at current values[15] creates a benefit to the citizens of Washington in the following approximate annual amounts:

SO_2- From currently 424 tons to 255 tons annually	=	$33,800.00
CO- From currently 1621 tons to 569 tons annually	=	$3,450.00
NOx- From currently 1572 tons to 885 tons annually	=	$1,200,000.00
Total savings of current value to public of Washington State	=	$1,237,250.00 annually.

In a review of the reduction of associated illnesses and the modeling of air quality, it does not appear the concentration levels will cause any increase or decrease in illnesses or premature deaths from the new lower limits.[16] The current standards appear to be below the standards set by the EPA in associated illness costs. The air quality was also modeled for SO_2 using both the current standards and the new proposed standards. The closest air monitoring station was reviewed for its data to spot maximum concentrations of SO_2. The modeling did not detect any exceedances of pollutant levels that represented a threat to human life. The monitoring station at Alexander Street in Tacoma, Washington did not show any unhealthy long term exceedances of SO_2 pollution levels during operation in the vicinity of the Tacoma Steam Plant from September 1998 through September 1999.[17]

The qualitative benefits will be the introduction of lower limits on currently controlled emissions and new limits on emissions that were not present in the WAC or monitored before.

3) The direct cost to the Tacoma Steam Plant is broken down as follows:[18]
    $300,000 - $500,000 carbon injectors (not mandatory)
    $100,000 per year ($20,000 per additional toxics test)

Ecology's public policy:

The Department of Ecology's public policy is to preserve, protect, and enhance the air quality for current and future generations. Air is an essential resource that must be protected from harmful levels of pollution. Improving air quality is a matter of state-wide concern and is in the public interest. It is the intent of this chapter to secure and maintain levels of air quality that protect human health and safety, including the most sensitive members of the population; to comply with the requirements of the federal clean air act; to prevent injury to plant and animal life and property; to foster the comfort and convenience of Washington's inhabitants; to promote the economic and social development of the state; and to facilitate the enjoyment of the natural attractions of the state (RCW 70.94.011).

It is, however, clearly articulated that Ecology’s preeminent objective must be the protection of public health and the environment. As a result, Ecology built into the proposed amendments the flexibility to modify compliance requirements in ways that both lower the cost to businesses and appropriately protect human health and the environment. Ecology was careful to maintain those elements of the proposed amendments needed to protect human health and the environment.

How does Ecology involve affected businesses and others?

Ecology will involve all interested parties by the use of meetings and mailings.

What are the reporting, recordkeeping, and other compliance requirements?

The proposed change to Chapter 173-434 WAC does contain several additional or new reporting and recordkeeping requirements. The addition of monitoring metals will increase recordkeeping and associated costs to test for them and the new limits. In some areas, it should actually reduce the burden by aligning state reporting requirements to federal reporting requirements**.** The acceptance of this proposed rule will also remove the time and temperature requirements which will allow facilities to discontinue temperature testing which may be expensive and time consuming. The emphasis will now be on emission testing of additional pollutants from the stack.

Will the proposed rule cause businesses to lose sales or revenue?

Ecology finds it unlikely that the proposed regulatory amendments will cause the affected businesses any sales or revenue losses. Ecology does not anticipate these amendments would cause a significant increase in down time but will allow Tacoma Steam Plant the opportunity to operate. Ecology also finds it unlikely that the proposed amendments will result in significantly higher prices. These facilities will be limited in their ability to pass through costs because of the nature of the businesses in this industrial category.

What professional services is a business likely to need in order to comply?

If these businesses are affected, it may need a variety of professional services to comply with the existing rule. The proposed rule should not change the need for this business to obtain professional services. If the business would need professional services to implement the existing rule, they will likely require professional services to implement the rule after the changes are in effect. In summary, to implement the existing rule or the proposed changes, this business may need to hire an accredited laboratory to extract and analyze samples and a consultant to interpret and report the results. Depending on the findings in the initial report, a business may need a consultant to prepare a remedial investigation and a feasibility study. In this case, the business may also need to hire a contractor to perform the actual requirements.

What about an exemption for creosote-treated wood products?

The state of Washington is currently drafting proposed language for Chapter 173-434 WAC in the operational standards of incinerators. The state of Washington is incorporating the federal standards of 40 CFR part 60 in the language of the WAC, along with lowering the threshold amount of material incineration, before the applicability of this WAC applies to the facilities. There was a request from the state of Washington Department of Ecology, Industrial Section to exclude creosote-treated fresh wood from the definition of solid waste while the rule is open. The intent is to make it more in line with the definition of the material found in other WACs.

Background:

Currently, in the state of Washington, a facility is burning railroad ties in Everett, Washington since December 1999 under a variance issued to them by Ecology. A test burn was conducted on this fuel in September 1999 for doing source tests for any increases in emissions. All factors that showed an increase were modeled by CH2M Hill to see if the burning of the creosote timbers would have any impact on the ambient air. The results show no significant difference in the emissions from control burns versus fuel containing creosote. The increase was in SO_2, but was within the facility's Annual Operating Permit (AOP) limits. It should also be noted that there was a decrease in the CO emissions.

Costs:

This facility has been using creosote timbers as a supplement to hog fuel that is usually burned at much higher moisture levels and lower BTU values.[19] The cost associated with the burning of creosote timbers is $10-15/ton for grinding and $2-3 for handling charges.[20] The monetary economics for this facility are favorable for continuing this fuel mix. Currently, in the United States, an estimated 10-15 million railroad ties (950,000 to 1,450,000 tons +/-) are replaced each year.[21] This creates a need for disposal in a number of ways. Approximately 34% are recycled for use in landscaping and other uses, 66% are sent for disposal in a landfill, and less than 4% are incinerated.[22]

In the case of Washington State, the proposed exemption of creosote timbers will increase the desirability of using this as a fuel to replace or supplement wood hog fuel. This exemption will make an impact as incinerators will not have to claim the burning of creosote as a solid waste material when it exceeds 12 ton per day of this type of fuel. The average cost of burning this material is roughly equivalent to hog fuel. The creosote railroad ties allow for a hotter fire temperature with lower average moisture content. This also allows for less material from railroads and other industries that have creosote materials as a waste to be put in landfill. The incinerator using creosote material is currently burning approximately 31,000 tons. The maximum limit of railroad ties the permit allows is 144,500 tons per year.[23] The money saved from the cost of landfill can be significant. In Snohomish County the cost of landfilling currently runs $89 per ton. This figure can change from county to county depending on the distance from a regional landfill. In Roosevelt County, for example, landfill costs are in the $19 per ton range, although the statewide non-weighted average for 2000 was $49.72 per ton.[24] For the purpose of this paper the cost of handling and preparation of the material for incineration is reduced from the avoidance of landfill cost ($18.00/ton).

Current Usage:

	Roosevelt Landfill	Average landfill	Snahomish landfill
Tonnage of ties	31,000	31,000	31,000
Net tip fee avoidance	$1 ($19-$18)	$31.72 ($49.72-$18)	$71.00 ($89-$18)
Profit/(loss)	$31,000	$983,320	$2,201,000

Variance Limit:

	Roosevelt Landfill	Average landfill	Snahomish landfill
Tonnage of ties	144,500	144,500	144,500
Net tip fee avoidance	$1	$31.72	$71.00
Profit/(loss)	$ 144,500	$4,583,540	$10,259,500

As seen from the above tables, the avoidance of landfill material from incineration ranges from a low figure of $31,000 to a high of $10,259,000 from this facility alone. The lower range is the most probable given the fact that the lowest cost landfill receives the most material in this state.

Conclusion:

Due to the fact that this industry is already under heavy regulation in a capital intensive arena, this proposed WAC amendment will be a natural step in the regulation of incinerators. The proposed changes to this WAC by implementing the federal standard of 40 CFR part 60, Subpart Eb are a refinement of years of study by the EPA and industry experience. This amendment is, at its basic level, the change to a performance-based emission output standard versus an interim regulation that dealt mainly with time and temperature standards. It makes sense to concentrate on what pollutants are actually being produced rather than to concentrate on how the operation of an incinerator is conducted. The proposed change to accepting the federal standard of 40 CFR part 60, Subpart Eb should allow for the citizens of Washington State and the industry to standardize expectations of incinerator emissions. There are currently two MSW facilities in Washington State and it is extremely difficult to place or construct a new facility anywhere in the United States.

The exemption for the Kimberly Clark facility simplifies the regulation of a boiler that has the distinction of not burning MSW but, because of dual regulation from another WAC, faces the problem of being subject to the same regulations as a MSW incinerator.

Appendix A: Tacoma Steam Plant Study

Tacoma Steam Plant No. 2 is a multi-fueled generating facility located on an urban site in the tide flats industrial area of Tacoma, Washington. The plant was originally built in 1931 and was repowered in the late 1980s with fluidized bed combustors to cofire wood, refuse-derived fuel (RDF), and coal. The repowered plant started commercial operation in August 1991. The plant is owned and operated by Tacoma Public Utilities, a municipal utility that provides water, electric, and rail service. On April 22, 1998 the Steam Plant was placed into reserve shutdown, and on June 15, 1988 the utility issued a Request for Qualifications for organizations to submit ideas and concepts about the possible acquisition or lease of Steam Plant No. 2 facilities and some adjacent properties.

Vital Statistics

Design capacity, net MWe	~40 (see discussion below)			
Configuration	2 bubbling FBC boilers			
		1995	1996	1997
Fuels, % by heat input:	Wood	54	60	68
	RDF	14	20	20
	Coal	32	20	12
Net heat rate, Btu/kWh		17,252	19,955	24,426
Thermal efficiency, HHV, %		19.8	17.1	14.0
Net generation, MWh/year		91,688	94,083	88,488

The Steam Plant's two turbine generators have a total rated capacity of 50 MW_e (gross). However, the capabilities of the combustion and ash removal systems constrain the plant's maximum output to the range of 30-40 MW, depending on the fuel blend. In brief tests, the plant has operated at levels up to 42 MW. During normal operations, the highest net output from the plant has been about 18.5 MW, running one combustor and one turbine/generator. The supply of RDF, the demand for power, and prices available in the secondary energy market has determined operating levels at the plant. In 1997 and 1998, the price of electric energy in the Tacoma market was generally less than 1¢/kWh. A biomass/waste-fueled plant cannot produce power at these low prices unless the fuels command substantial tipping fees. Steam Plant No. 2 operated only as much as necessary to burn the RDF it received -- resulting in net generation rates of about 11-13 MW over the period 1994-1997. The plant has burned, on average, about 60% wood, 20% RDF, and 20% coal.

History and Outlook:

Steam Plant No. 2 was originally built in 1931 as a 25 MW coal fired steam generating facility (later modified to burn oil and expanded to 50 MW) to supplement the area's hydroelectric power supply during low-water years. It was removed from service in 1973 because of problems with the super heaters and the capital expenditures necessary to bring the plant within full environmental compliance. At the time, it had logged less than one year of cumulative operation.

A feasibility study conducted in 1974 concluded that it would not be economical to refurbish the plant for continued peaking or base load service. A 1979 plan to convert the facility into a cogeneration plant looked promising, but was halted because local industries would not commit to long-term steam contracts.

In 1984, Energy Products of Idaho (EPI), a fluidized-bed manufacturer in Coeur d'Alene, Idaho, approached the City with a proposal to lease Steam Plant No. 2, refurbish and operate the facility, and sell power to Tacoma Power. Because of legal technicalities, the project could not be conducted with private ownership, but it looked attractive to Tacoma Power. After a feasibility study and several months of negotiations, the City took over the project in the spring of 1986. In 1986, the City of Tacoma applied for and was awarded a $15 million matching grant from the Washington State Department of Ecology. The grant was used by both Tacoma Power for repowering Steam Plant No. 2 and by the local refuse utility for modifying its resource recovery facility to produce RDF. Moorhead Machinery & Boiler Company, a subsidiary of Westinghouse Electric Corporation, was selected to complete the design and construction. The total cost for the renovation of Steam Plant No. 2 was approximately $45 million.

The plant began startup testing in December 1989 and was running on all three fuels by April 1990. Acceptance testing was performed starting in May 1990. Commercial operation began August 1, 1991. Power Magazine (April 1991), in awarding Steam Plant No. 2 its 1991 Powerplant Award, stated that "the major goal of the repowering project is to generate as much power as possible -- or as dictated by electric demands -- at the lowest cost, while combusting all of the city's 300 tons/day of refuse-derived fuel (RDF)." As it turned out, the amount of RDF delivered by the city's Refuse Utility and burned by Steam Plant No. 2 during the years 1993 through 1997 ranged from 28,539 to 48,412 tons/year, or about 78 to 133 tons/day.

Several design and mechanical problems were solved between 1991 and 1994, and a reliable mode of operation was established, which involved running one combustor at a time while the other was maintained on standby. From 1994 through 1997, net plant output was equivalent to about 11 to 13 MW, with an on-stream factor of about 86-87%. Plant availability (to operate one combustor at a time and consume RDF) was maintained in the 90-96% range. Initially, the cost of power from the plant was competitive within the utility's system, but dramatic drops in market prices for electricity made the plant uneconomic. Significant reductions in fuel cost were achieved in 1997, and a plan was developed to convert the plant to a tipping fee facility that would generate net revenues from most or all of its fuels. Implementation of this plan required modifications to the plant's air quality permit, which were underway when Tacoma Public Utilities put the plant on reserve shutdown in 1998. The future of the plant depends on the outcome of negotiations with the successful bidder, on the operating and business strategy pursued by the new owner, on alternative disposal options for MSW, and on developments in electricity and fuel markets.

The repowering project consisted of the installation of two bubbling atmospheric fluidized-bed combustors, four refractory-lined cyclones that allow ash and unspent limestone to be reinjected into the combustors, and ductwork that connects the combustors to the existing boilers, which were converted to heat recovery steam generators (HRSGs). In addition, the project included the installation of a mechanical draft cooling tower to replace the use of salt water from the Hylebos waterway for steam condensing, the installation of fuel handling, pollution control and ash handling equipment, and the installation of a continuous emissions monitoring and computerized distributed control system.

Combustors

The bubbling fluidized bed combustors provided by EPI were designed to cofire a combination of wood waste, coal, and RDF. The design values were 15% RDF, 35% wood, and 50% coal. The combustors are capable of firing 0-100% wood, 0-50% coal, and 0-50% RDF (permit limitation). The fuel mix is fed to the FBCs overbed, while limestone is added directly to the beds for SO_2 absorption. Bed temperatures are maintained at approximately 1,550°F to minimize ash agglomeration and maximize sulfur capture. The combustors are designed for a total fuel input of 831 MBtu/hour, which corresponds (at full rated net output of 50 MW) to a net plant heat rate of about 16,620 Btu/kWh. The permit limitation is 718 MBtu/hour. Combustion air is provided by 1,500 hp forced-draft fans directly to the fluidizing air manifold of each combustor, with no air preheat.

Refractory-lined cyclones (two per combustor) installed between the combustors and the heat recovery steam generators (HRSGs) capture ash and unspent limestone for reinjection into the combustors. The refractory -lined cyclones are 18 feet in diameter and capture particulate matter larger than 30 microns. Reinjection ensures complete combustion, reduces the amount of fly ash to be removed downstream by the plant's fabric filters, and enhances limestone utilization. The reinjection system was disabled soon after startup because of excessive wear problems. As a result, lime has been used instead of limestone for SO2 control. (Lime is more expensive than limestone.)

The combustor operations most closely resembles a bubbling bed process although the combustion air flow is great enough to carry some limestone and smaller unburned fuel particles from the combustion unit into the cyclone separators, somewhat like a circulating FBC process. The configuration of the combustors relative to the HRSGs gives a minimum of 5 seconds of residence time for the flue gas at temperatures of approximately 1,600°F.

Heat Recovery Steam Generators

The existing boilers were converted to HRSGs by removing the burners and installing steam separation equipment, external superheaters, and economizers. Refractory ducting conveys the flue gas from the combustors through the cyclones to the waste heat boilers. The superheaters are mounted in the hot gas ductwork just ahead of the existing boiler fronts. This configuration allowed shop fabrication of the superheaters and located them in a very hot section of the flue gas stream (where the temperature is generally above 1,650°F). The superheaters employ bare, horizontal tubes with vertical headers, allowing full drainage of the units.

Steam Generation

In the forced circulation feedwater loop, water is taken from the front boiler drum by gravity flow to a new steam separator tank next to each combustor. Each tank provides suction for two 50%-capacity pumps that circulate the water through the combustors heat removal tubes. These tubes help to maintain desired bed temperatures, while evaporating approximately 60% of the feedwater.

The water/steam mixture from the combustors returns to the separator tanks where water is fed back to the circulation loop; steam continues on to the front drum of the existing boiler. The steam is then directed through each boiler's rear drum and into the external superheaters. Final steam conditions are 750°F and 400 psig. Either of the combustor-boiler combinations can supply steam to drive either of the two steam turbines.

Ash and Tramp Material Removal

Fly ash is collected from the fabric filters and pneumatically conveyed to a silo that stores 900 tons or approximately seven days of production at maximum generation levels. Ash is also collected from the hot cyclone separators, HRSGs, and economizers. The ash is discharged from the silo through a conditioner into trucks for transport.

Each fluidized-bed combustor is equipped with a system to continuously remove undesirable material (tramp) from the bed media. The system allows bed media to flow from the cones making up the bottom section of each combustor (eight cones per combustor) through timed slide gates onto a divided vibrating pan conveyor. The vibrating pan conveyor is divided into two layers by a screen. As the bed media travels along the conveyor, the smaller particles pass through the screen and are transported to a bucket elevator for recycle into the combustor. The larger material that does not pass through the screen is primarily composed of glass, metal, rocks, and agglomerated bed media.

Fuel System

Wood and RDF are delivered to a covered storage building by truck. These fuels are reclaimed from the storage building by ladder-type chain reclaimers and deposited on a drag chain conveyor. The conveyor deposits the wood/RDF mixture onto a belt conveyor for transfer to the fuel metering system. In addition, some wood is stockpiled in a nearby storage area. This area was designed as a full-scale ash demonstration project using fly ash and lime as a sub-base stabilizer for an asphalt application.

Wood fuel suppliers weigh in and out through an automated scale system and deposit their loads into a single truck dumper. The hog fuel passes over a disc screen and the overs that accumulate are re-sized by the Solid Waste Utility at no cost to the Steam Plant. The fuel is conveyed to one of five bays in the fuel building or deposits at an overflow bay at the end of the building. Normally, fresh wood is deposited at the overflow area and is stacked by loader on a current pile being built. The fuel handler also reclaims the wood and stages it under one of the reclaimers in the fuel house. Typically, bays 4 and 5 are used for RDF.

A mix of wood and RDF is forwarded to the metering system on a belt conveyor. This mix passes under an electromagnet and over a magnetic head pulley to capture ferrous materials. The ratio of wood to RDF is established in the fuel house by gates over the drag chain that delivers fuel to the forwarding belt. The wood/RDF metering system was replaced with a totally redesigned auger system that can feed and meter a wide range of wood, RDF, and mixed fuels. This system can feed and meter almost any sized material 6 inch minus, and has also been successfully tested with coarser RDF in the wood-RDF mix. Key factors in the success of the wood/RDF metering system include:

- All stainless construction (except for AR flighting of augers)
- Negative slope bin with minimal surface discontinuities
- Large (28 inch OD) augers with continuously varying pitch
- Large (20 inch square) discharge chutes
- Hydraulic drive for infinite control and full torque at low feed
- Ultrasonic level control

Coal is delivered to the plant by self-unloading barges or trucks. The barges are moored in the Hylebos Waterway where they transfer their contents to a series of belt conveyors that place the coal in a storage pile. The coal is then moved from the storage pile by a wheel loader to a reclaimer that feeds a series of belt conveyors. The conveyors transport the coal into the existing day bunker in the boiler building where it is then forwarded to the combustor fuel metering system. The coal feed system was also replaced with auger feed equipment. The 10 inch standard AR augers are driven by 5 HP motors with Woods inverter electronic drive. The turndown is limited by low speed torque needs, but the fluidized bed system allows use of one, two, or three feeds as needed to achieve low end performance.

Emissions Control

Granular limestone is injected into the fluidized bed combustors to control SO_2 emissions. The limestone handling system consists of a silo, where truck deliveries are accepted; a variable-speed drag chain conveyor, which delivers the limestone to a flow splitter at the combustors; and a bucket conveyor, which carries the limestone into the combustors.

Two fabric filters, one for each flue gas exhaust train, control particulate emissions. Each baghouse has 1,920 6-inch diameter by 14-foot long fiberglass bags. The filters are designed to remove 99.8% of the particulate matter from the flue gas. Two 600 hp induced draft fans direct the two flue gas streams to a common 213-foot tall stack.

In 1997, an alkali sorbent injection system was installed upstream of the baghouses to remove trace amounts of HCl from the flue gas. The scrubber uses trona (sodium sesquicarbonate) to react with the chlorine to form sodium chloride (table salt), which is removed along with the fly ash in the fabric filters. The chlorine originates primarily from plastics and other chlorine-containing materials in the RDF. Uncontrolled HCl emissions were typically about 260 parts per million in the flue gas; with lime and trona injection, HCl emissions drop to about 19 ppm. Overall HCl removal efficiency averages about 93%.

Plant Control

The plant is controlled by a distributed control system (DCS) supplied by Westinghouse Electric Corporation. Control is accomplished through the combination of local programmable logic controllers (PLCs) and direct connection of the DCS central computer to the process. All systems critical to the immediate operation of the plant are automated through the DCS and are under the control of the operator. Stand-alone systems such as ash handling are controlled by PLCs, with monitoring and limited operational control from the DCS.

Staffing

During plant operation, Steam Plant No. 2 is staffed with a crew of three, working 12-hour shifts per day. The crew consists of a control room operator, a roving auxiliary operator, and a fuel handler. Additionally, during normal business hours the plant is staffed with a plant manager, plant assistant manager, office assistant, relief control room operator, auxiliary operator and fuel handler, one electrician, one mechanic, and two engineers. The total staff onsite during normal business hours is approximately 21 to 28 employees.

Fuels

As shown in the table below, the largest contributor to the fuel mix on a heat input basis has been waste wood (54-68% in 1993-1997). Coal, the most expensive fuel used, accounted for 27-32% of the total during 1993-1995, but its use was reduced to 12% in 1997 as cost reduction became paramount. RDF, the zero-cost, "must-burn" fuel, accounted for 12-20% of the total heat input to the plant in 1993-1997.

Waste Wood

During 1993-1996, all of the waste wood for the plant was purchased on the spot market from about 100 authorized suppliers. About 64% of the wood fuel was from mill and logging sources, 23% from land clearing, and the remaining 13% from urban and industrial waste. Moisture content ranged from 22% to 55%. The annual average price paid by the plant for wood waste ranged from $0.72/MBtu to $0.88/MBtu during 1993-1996. Wood waste prices tend to increase significantly during the winter months.

Beginning in 1997 a concerted effort was made to obtain lower-cost wood fuel, resulting in an annual average price of $0.28/MBtu. In 1997, approximately 65 active vendors supplied waste wood to the plant on a spot market or tipping fee basis. Storm debris in February and land clearing wood in May through October were obtained at zero or nearly zero cost. The reduction in the cost of wood, plus the reduction in the amount of coal burned (which cost over $1.70/MBtu), reduced the plant's fuel bill by over $600,000 from 1996 to 1997.

RDF

The City of Tacoma Refuse Utility delivers RDF at no cost to the Steam Plant. After sorted residential garbage reaches the Tacoma Resource Recovery Facility, it is shredded, air classified (separated by density), and mechanically separated. The mechanical separation steps include a drum magnet that separates ferrous metals, a primary disc screen that sends oversize material through a secondary shredder back to the feed point, and sends undersized material to a secondary disc screen that discharges grit (undersized material) to be landfilled, and RDF (oversized material) to a compactor, which feeds the compacted RDF to trucks that carry it to the Steam Plant. Ferrous metals are recycled, while light plastics, paper, and wood are compacted into RDF. Any newspaper that is not separated at drop off recycling sites becomes part of the RDF. A small portion of the city's yard waste ends up in the RDF as well, but most of the yard waste goes to a private topsoil firm for recycling. There is a separate drop-off center at the landfill for batteries, and crews on the tipping scales, tipping floor and curbside are trained to separate out household batteries. The noncombustible portion of the garbage processed at the resource recovery facility is landfilled. In a Memorandum of Understanding between the Solid Waste Utility and Tacoma Public Utilities, the Solid Waste Utility committed to producing and delivering to Steam Plant No. 2, at its sole expense, between 100 and 350 tons/day of RDF conforming to the fuel specification in the agreement. Tacoma Public Utilities committed to receive, store and incinerate the RDF at its sole expense. This arrangement is open to renegotiation for future owner/operators of Steam Plant No. 2. In 1997, Steam Plant No. 2 burned 39,540 tons of RDF at an average rate of 125 tons/day. (Weekday deliveries averaged 150 tons/day.) The Solid Waste Utility has indicated that it has an interest to increase RDF production.

Combustion of RDF is currently limited to 30% by weight as stated in the PSAPCA Notice of Construction issued January 27, 1998. This restriction allows the plant to operate as a cofired combustor and avoid compliance under the Municipal Waste Combustor rules (Subpart Cb of 40 CFR 60).

Year	1993	1994	1995	1996	1997
Fuel burned, tons/year:					
Wood	175,806	118,511	87,949	118,997	162,900
RDF	48,412	32,812	28,539	42,188	39,540
Coal	39,563	33,262	25,539	19,373	13,295
Fuel HHV, Btu/lb:					
Wood	4,929	4,929	4,833	4,730	4,521
RDF	4,546	3,918	3,886	4,556	5,361
Coal	9,907	9,875	9,983	9,480	9,948
Fuel burned, MBtu/year:					
Wood	1,733,096	1,168,281	850,115	1,125,712	1,472,942
RDF	440,162	257,115	221,805	384,417	423,948
Coal	783,901	656,925	509,912	367,312	264,517
Total	2,957,159	2,082,321	1,581,832	1,877,441	2,161,407
Fuel burned, % by heat:					
Wood	59	56	54	60	68
RDF	15	12	14	20	20
Coal	27	32	32	20	12
Fuel prices, $/ton:					
Wood	8.52	8.68	7.00	7.19	2.53
RDF	0.00	0.00	0.00	0.00	0.00
Coal	35.61	33.88	33.50	34.03	34.42
Fuel cost, $/year:					
Wood	1,497,867	1,028,675	615,643	855,588	412,424
RDF	0	0	0	0	0
Coal	1,408,838	1,126,917	855,557	659,263	457,615
Total	2,906,706	2,155,592	1,471,200	1,514,852	870,039
Fuel cost, $/MBtu:					
Wood	0.86	0.88	0.72	0.76	0.28
RDF	0.00	0.00	0.00	0.00	0.00
Coal	1.80	1.72	1.68	1.79	1.73
Total	0.98	1.04	0.93	0.81	0.40
Gross generation, MWh/year	160,311	120,274	113,290	114,557	109,881
Net generation, MWh/year	130,253	97,091	91,688	94,083	88,488
Fuel cost, ¢/kWh	2.2	2.2	1.6	1.6	1.0
Net heat rate, Btu/kWh	22,703	21,447	17,252	19,955	24,426
Thermal efficiency, % (HHV)	15.0	15.9	19.8	17.1	14.0

Coal

Obed coal from Oxbow Carbon & Minerals, Inc., Canada, and Decker Coal from Kiewit Mining in Wyoming have generally been the lowest cost coals available to the plant that met the PSD (air quality) permit requirement of less than 0.8% sulfur. The Obed coal is shipped by barge. The Decker coal is transported by rail to a nearby rail unloading facility, where it is transloaded onto trucks and delivered to the plant.

Natural Gas and Fuel Oil

Natural gas and fuel oil are used during startup. These fuels accounted for less than 1% of the total fuel consumption, and are not included in the fuel consumption figures shown in the table. Each combustor has two 50 MBtu/hour above-bed gas burners, which operate during startup until the flue gas temperature is raised sufficiently to allow the baghouse to be put into service. Each combustor also has a 10 MBtu/hour distillate fuel oil burner located in the air supply plenum, which is used to heat the fluidized bed during startup.

Opportunity Fuels

The fluidized bed combustors are able to burn a wide variety of fuels. Finding more "opportunity fuels" that command a tipping fee or can be obtained free became a high priority in 1997. The plant had received some wood for free, usually in winter and early spring as a result of major storms. Cities and counties paid the cost of collecting, processing, and delivering the storm debris to the plant, which was less expensive to them than landfilling it. Analysis showed that by setting up a wood processing yard onsite instead of buying prepared wood fuel from wood processors, the plant would be able to charge fees of about $15-25/ton for stumps, tree wastes, and other wood wastes. The cost of grinding these materials onsite would be about $5-15/ton. Wood processing yards in the area charge tipping fees for these types of wood wastes ranging from $31 to $46 per ton.

In addition, the utility investigated the possible use of a variety of industrial wastes, such as asphalt roofing shingles (tear-offs), wood laminates, on/off-specification oil, oil sludges, oil-contaminated sorbents and rags, textile and plastic waste, green petroleum coke, non-recyclable paper waste, and pulp mill clarifier solids, that could generate revenues if they were acceptable fuels. Tipping fees for some of these items are in the $80-100/ton range, and transport distances to facilities that accept them are over 100 miles. Burning some of these petroleum-based waste fuels might allow the plant to operate with no coal in its fuel mix. Technically, it is believed the bubbling fluidized bed combustors and environmental control systems at the plant could handle any of these fuels. During 1997-1998, Tacoma Public Utilities acquired permits and developed a test burn plan for many of these fuels. The permits allow a 180-day period to burn the various fuels and conduct all necessary testing and monitoring to determine operational constraints required to assure compliance with current regulations. By eliminating coal and replacing most or all of the purchased wood with tipping fee wastes, the plant's annual fuel cost, which in 1997 was still almost $870,000/year or 1.0¢/kWh, could be converted to a net revenue stream of at least that amount, and possibly more.

Operating Experience

Significant improvements have been made to the fuel feed, combustion, and control systems since 1991. The plant has demonstrated successful operation on a wide variety of fuel mixes, including wood only, wood and RDF, coal and RDF, wood and coal, and varying combinations of all three fuels. Major factors that negatively impacted power production and availability during early operations were:

Shutdowns to remove wire from the combustors. Wire comes in the RDF and hangs up on the air manifolds, forming large nests that impede air flow in the combustor.

A slagging condition in the combustor and cyclones that increases with increased firing rate and vapor temperatures.

A fuel feed and metering system that delivered fuel to the combustor in an erratic manner. This fuel feed system was replaced in the fall of 1994.

Insufficient heat transfer surface in the fluidized bed. More surface was added to increase the steam production capability.

Fuel consumption, electricity generation, and plant efficiency data for the years 1993 through 1997 are shown in the table above. Basically, the plant was run at the rate needed to consume all of the RDF delivered. In 1994-1997, the net generation was in the range of 88,000 to 97,000 MWH/year, which is equivalent to production of 11 to 12 MW during the 7,500-7,700 hours per year that the plant operated. The RDF provided about 12 to 20% of the heat input, and the remainder by wood and coal, as required by the plant's air quality permit conditions and operating considerations.

Usually, one FBC unit operated while the other received maintenance or sat in standby condition. After 2-3 months of operation, the operating unit was shut down for inspection and maintenance and the other unit was started up. In 1997, for example, unit 1 operated 4,127 hours and unit 2 operated 3,535 hours, giving a total plant operating time of 7,662 hours, or 87.5% of the 8,760 hours that year. Plant availability (operating one combustor at a time, to consume RDF) was 95.8% in 1995, 92.4% in 1996, and 93.4% in 1997.

Because of the plant's unique (retrofitted) design and low steam temperature and pressure, the thermal efficiency of Steam Plant No. 2 is relatively low. As the table above shows, the net plant heat rate increased from 17,252 Btu/kWh in 1995 to 24,426 Btu/kWh in 1997 as the percentage of coal in the fuel mix decreased from 32% to 12% by heat input. The heat rate would improve if the plant were run closer to its design output. If the development of an onsite fuel processing capability produced a net revenue stream from tipping fee fuels, then improving the plant's thermal efficiency would not be an important consideration.

The auxiliary power requirements of Steam Plant No. 2 (the difference between gross and net generation) are also relatively high, at about 18-20% of the gross MWh/year. This is also explained by the unique (retrofitted) plant design and by the low capacity factor at which the plant has operated.

Environmental Performance

Steam Plant No. 2 has met or operated significantly below all required state, federal, and local air emission requirements. Fluidized bed combustion with limestone injection results in very low SO_2 and NO_x emissions. The fabric filters remove 99.8% of the particulate matter from the flue gas stream. A continuous emissions monitoring system measures SO_2, NO_x, CO and O_2 levels in the exiting flue gas. Opacity is measured and gives a rough indication of particulate concentration. In 1997 an alkali sorbent injection system was added upstream of the baghouses to remove HCl from the flue gas. Operation of this unit has been successful, with over 90% HCl removal.

The permitted emissions, with the control method used, are as follows:

SO_2 -- 0.18 lb/MBtu 30-day rolling average or at least 70% control. Control -- Lime or limestone injection and the use of a low (0.8% or less) sulfur coal.

NO_x -- 0.50 lb/MBtu (hourly average). Control -- Maintain temperature in combustion zone at 1,450-1,550°F.

CO -- 0.52 lb/MBtu or 425 ppm (hourly average). Control -- Proper combustion control, 5-second residence time.

Opacity -- 10% for an aggregate of more than 3 minutes in any 60-minute period; 5% hourly average. Control -- Baghouse.

Particulate matter -- 0.010 grains per standard dry cubic foot of flue gas, corrected to 7% oxygen total catch, 0.0068 grains/dscf front half catch (first test indicates 0.004 g/dscf actual). Control -- Baghouse with Ryton Filter Bags.

Nearly all of the plant's generation byproducts (fly ash, aggregate, and tramp residues) are recycled. An extensive three-year ash testing program culminated in April 1994 when Tacoma received a Certificate of Designation from the Washington State Department of Ecology certifying Steam Plant No. 2 fly ash as a solid waste under federal and Washington State laws. Most of the ash is used for waste stabilization of oily sludge's; some is sent to a cement manufacturing facility in Seattle where it is used to displace clay in the cement manufacturing process. Some of the ash is also being used as a soil amendment in mine reclamation efforts. The tramp, or bottom ash material, is separated and the aggregate portion used as a road base material. The metals are sold to a recycling facility and the remaining tramp, consisting mostly of glass, wire, plastic, and clinkers, is then landfilled.

In the last five years of operation, the ash generated has averaged 14,000 tons/year. More than 98% of the ash generated in 1997 was supplied to users at an average cost to the utility of about $3/ton. In 1997, 242 tons of ash was landfilled at a cost of about $36/ton.

Economic Information

The total cost for the renovation of Steam Plant No. 2 was approximately $45 million, partially funded by a $15 million grant from the Washington State Department of Ecology. In 1993, the variable cost of power from the plant averaged about 4¢/kWh, 2.2¢ of which were fuel costs. At that time, this 4¢/kWh cost was lower than the costs of power from other potential resources that were being considered for development by Tacoma Public Utilities. It also favorably offset the purchase of outside power from the Bonneville Power Administration. The situation had changed by 1996-1997, however. Although the plant's fuel cost had been reduced to 1.6¢/kWh in 1996 and 1.1¢/kWh in 1997 (annual averages), and the variable cost of power from the plant was in the 1.5-3¢/kWh range, the energy market in the Pacific Northwest had dropped to about 0.5¢/kWh (off-peak) and 0.7-0.8¢/kWh (on peak).

In early 1998 Tacoma Public Utilities was operating Steam Plant No. 2 at an estimated loss of about $3,000,000/year. The Solid Waste Utility was benefiting from the combustion of RDF by about $1,000,000/year, so the city-wide loss was on the order of $2,000,000/year. Work was proceeding on the modification of the plant permits to allow onsite processing and combustion of tipping fee fuels, which would allow the plant to eliminate the loss at some point in the future. In April 1998, Tacoma Public Utilities put the plant up for sale.

Lessons Learned

Plant personnel suggested the following lessons learned from their experience at Tacoma Steam Plant No. 2:

Fuel

Fuel, fuel, fuel to a biomass/waste fueled power plant is like location, location, location to a realtor. Don't box the facility in with a limited fuel supply and/or permit. The more options the better.

Fuel procurement should be one of the highest priorities and a full time job.

Obtain a low cost fuel supply in sufficient quantities to maximize generation.

Focus on fuel cost (¢/kWh) rather than fuels that provide highest efficiency (Btu/kWh) - saved the plant $600,000/year in coal costs. Opportunity fuels (with tipping fees) have the potential to eliminate fuel costs and generate net revenues.

Carefully evaluate the real costs of zero cost or tipping fee fuels. There are always costs associated with fuel preparation and combustion that the plant must absorb.

RDF fuel quality - elimination of aluminum and copper wire from RDF would make this a more acceptable fuel. These elements significantly contribute to bed fouling and slagging which cause frequent plant shutdowns. The elemental aluminum in the fly ash decreases its marketability. If the RDF were denser, the plant efficiency would improve due to combustion in the bed rather than in the vapor space. Acid gases from chlorine in the RDF require additional sorbent expense and an injection system.

Fuel Feed System

Take extra care at the beginning of the project with design of the fuel feed system. Go with a proven fuel feed system; don't let someone sell you an unproven feed system.

Make certain that fuel quantity can be accurately measured. Because wood and RDF are transported to the combustor on one conveyor and commingled, Tacoma is unable to accurately measure the quantity of each delivered to the combustor. These measurements are of obvious importance in recording heat rate and economics. Redundancy and overall control of the process is sacrificed.

Plant Design

Fuel flexibility - when developing combustor design and environmental permits for a new plant, this should be one of the highest priorities. A CFB or increased height on the combustors would have been more appropriate - to eliminate slagging problems.

Design the plant for worst case scenario fuels and for easy clean out. The Tacoma plant needs a sand storage system that cleans, stores, and transports bed media during the combustion cleanup process with minimum manpower.

Expect fouling (especially with RDF in the fuel mix). Design the facility for easy cleanup and perhaps with on line cleaning ability to minimize down time. A preventative maintenance program is essential.

Operation

Develop and follow standard operating procedures that eliminate operator variables and give more consistency in operations. This avoids see-saw up and down operations that shorten run time. It also helps identify problems quickly. If the procedure is not working it can be more easily identified and corrected.

Multitasking of labor - train and assign personnel to do more than one job.

Focus on preventative maintenance to reduce operating costs.

Ash Marketing

Ash marketing/sales rather than disposal - saved the plant $600,000 per year.

Design the ash handling system to optimize ash as a product. That might mean that the ash system drops out and stores ash at different locations for different applications and better marketability.

Research ash markets and determine just what the plant will be producing with each anticipated fuel mix combination; then market it. Landfilling ash should be the last resort.

Sources and Contacts

Much of the descriptive information in this report section was obtained from the following published sources:

Power Magazine, April 1991. "Bubbling Bed Combustors Achieve True Cofiring of RDF, Wood, and Coal."

Independent Energy (reprint not dated). "Fluidized Bed for Resource Recovery", by Patrick McCarty, P.E., Tacoma City Light and Thair Jorgenson, P.E., Tacoma Refuse Utility.

Proceedings: Strategic Benefits of Biomass and Waste Fuels. Electric Power Research Institute (EPRI) TR-103146, December 1993. "RDF/Wood/Coal Cofiring at Tacoma City Light Steam Plant No. 2", by Mark B. Gamble.

Request for Qualifications for Steam Plant No. 2 Business Opportunities, Tacoma Public Utilities, June 15, 1998.

Mark Gamble was the Steam Plant Manager from startup through September 1997, when he left to become plant manager of a large fluidized bed project in Thailand. Laurie Hannan was Assistant Plant Manager until September 1997, when she was promoted to Plant Manager. Dan Rattler, P.E., was Plant Engineer since February 1995. These people were very generous with their time and helpful in providing information and reviewing this report section.

Contact information:

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CITY OF TACOMA STEAM PLANT NO. 2, TACOMA, WASHINGTON –

Appendix B: Spokane Facility study

Waste Disposal

The Waste to Energy Facility is located on a 52-acre site approximately 1.5 miles west of the city limits, on land leased from the Spokane International Airport Board. Two overhead cranes mix and sort the waste and deliver it to the two waterwall furnaces for incineration. Each furnace has a design capacity of 400 tons per day, but due to conservative design parameters, they have been able to operate in excess of that amount. All electricity generated by the facility, except that used for in-plant purposes, is sold to Puget Sound Energy. These revenues are income to the system. The ash generated by the combustion process is approximately 32% of the incoming material by weight, but only about 10% by volume.

The facility processed 268,390 tons of solid waste in 2001, resulting in 71,242 tons of ash and 10,337 tons of recovered ferrous metals. An additional 12,175 tons of waste were disposed in the North Side Landfill and 31,140 tons were bypassed to the Rabanco Regional Disposal Company, for a total of 312,676 tons. Subtracting the recovered metals and an additional 971 tons of white goods from the Waste-to-Energy receiving floor, net disposal for 2001 was 301,368 tons. The facility produced 166,998 megawatt hours of electricity in 2001 and sold 136,671 MWH, with net revenue of $11,570,485.26. (The revenue per kilowatt-hour increased from 4.2 cents in 2000 to 8.9 cents in 2001.) Although income from electricity sales went up by $6 million, debt service was also structured to increase by a corresponding amount last year.

Facility Highlights

GENERAL

Area served.	Greater Spokane Area/418,000 people
Type of contract.	Full service/Operate
Ownership.	City of Spokane
Financing.	Revenue Bonds/Department of Ecology Grant
Start-up	1991

REFUSE COMBUSTION

Type of system.	Waterwall boilers
Operation.	24 hours per day, 7 days per week
Process lines.	2 @ 400 tons-per-day
Plant daily capacity.	800 tons
Average throughput.	680 tons per day (365 days)

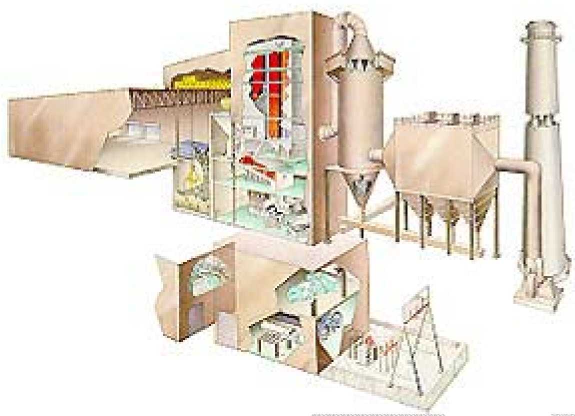
Feed system. . . . . 2 overhead refuse cranes with ram feeder
Grate design. . . . . Von Roll reciprocating
Combustion temperature. . . . . 2500° F+
Auxiliary fuel. . . . . Natural gas
Waste volume reduction. 95%
Ash handling system. . . . . Semi-dry, vibrating pan conveyor
Materials recovery. . . . . +10" metals, aggregate, ferrous

AIR QUALITY CONTROL

Type of equipment. . . . . Dry scrubbers-Fabric filters-deNO$_x$
Number of units. 2

ENERGY PRODUCTION

Type of energy. . . . . Electric power
Steam flow to turbine. . . . . 188,000 pounds per hour @ 830 psig/825° F
Electric power capacity. . . . . 26 megawatts
Cooling system. . . . . Air cooled condenser
Customer. . . . . Puget Sound Power and Light Inc.



Facts & Figures

Plant Capacity

=800 Tons/day, using two 400/ton per day boilers. Guaranteed capacity of at least 248,200 Tons/yr.

Electrical output

26 megawatts gross - 22 megawatts net enough to light 13,000 homes

Turbine Speed

3600 rpm producing 60 Hertz (60 cycles/sec)

Pit Dimensions & capacity

140' x 50' x 40' + 40' back wall; 4800 tons

Receiving floor

62,000 square ft. or 1.4 acres

Stack

175' tall, preformed concrete sections, contains three flues

Fire Temperature

2500 degrees F

Temp/Velocity of exiting stack gases

250 degrees F, 4000 ft per minute

Construction involved

16,415 cubic yards of concrete
198,692 cubic yards soil imported
45,251 feet of pipe
3,248 Tons of structural steel
350,829 feet/66.445 miles of cable

10,740 feet/2.3 miles of cable tray
2,396 field welds
Time to construct
22 months
First refuse fire
September 6, 1991
Refuse crane
capacity = 9 tons or 6.5 cubic yards; Typical load = 2-3 tons
Computer System
Bailey Network 90
Cost
110 Million dollars, largest capital project for City of Spokane
Ownership
City of Spokane
Service Area
City of Spokane & Spokane County & all municipalities within
Wheelabrator involvement
Design, construct, operate and maintain for 20 years
Similar technology
Wheelabrator operates 13 other similar facilities in the U.S. There are over 500 plants in the world, approximately 136 using the same basic technology. More than 20 equal to or larger than 800 TPD
Ash Quantity
90% reduction by volume; 68% reduction by weight of original MSW weight
Ash Disposal
Rabanco Regional Landfill, Klickitat County (near Roosevelt, WA)
Ash Transport
Container capacity 15 tons. Configuration: two containers per load 30 tons per truck, 8-10 truckloads/day. Intermodal train container, 25-28 ton capacity
Metals recovery
2.5% of original weight of MSW. Metal is not recovered with traditional landfilling.
Built for expansion
Extended Conveyors; Big pit; Extra flue in stack; Boiler + APC + turbine needed
Air Cooled Condenser
Totally dry cooling-6 cells, 150 HP motors
Boiler tube length
Approximately 100 feet, suspended from roof structural steel
Bag Houses
Bag houses contain 3420 bags (1710 per boiler line). Filtering bags are made of Gore-Tex fabric.
Continuous Emission Monitors
Read every 15 seconds-02, S02, Nox, Opacity, CO, Temperature
Property Area
52 Acres
Regulatory Agencies
Spokane Air Pollution Control Authority (SCAPCA), Washington Department of Ecology (WDOE), and Spokane County Health District (SCHD).
BTU values
Garbage = 4,800/pound
Coal = 12,000/pound

Plastic = 14,000/pound
Tires = 16,000/pound
RR Ties = 7,000/pound

Problem

Environmental concerns associated with continued landfilling, new Washington State solid waste regulations and federal actions directly affecting Spokane area landfills led the City and County to jointly develop a comprehensive program for regional solid waste reduction, recycling, recovery of energy, and residue disposal. This cooperative effort resulted in the Spokane Regional Solid Waste System, which includes the Waste to Energy Facility, North County Transfer Station, and Valley Transfer Station. Each of these facilities has a recycling center and household hazardous waste turn-in area on site. Ash produced from the waste to energy process is sent to an ash monofill at Rabanco's Roosevelt Regional Landfill in Klickitat County, WA. In addition, there is an active cell at the Northside Landfill that is available for bypass and non-processible materials collected by the System. These facilities are intended to provide long-term, environmentally sound solid waste disposal for both the City of Spokane and the other incorporated and unincorporated areas of the County.

System Planning

In response to the *Final Report and Water Quality Management Plan to Preserve Spokane's Sole-Source Aquifer* (April, 1979), a consortium consisting of the City, County, and the Washington Water Power Company, hired Morrison-Knudsen in 1982 to conduct a feasibility study of various solid waste management systems. They looked at 10 different scenarios and ranked them according to environmental and economic criteria. The final report was completed in 1983, and it recommended that a waste to energy facility be included as part of the new Regional Solid Waste System.

In 1983, the County developed the Comprehensive Solid Waste Management Plan to address the solid waste management and disposal needs of the Spokane area. The Comprehensive Plan was adopted in 1984 by the County, the City and all other incorporated cities in the County (with the exception of the Town of Rockford). It was also subject to environmental and public review and subsequent conditional approval in 1986 by the Washington State Department of Ecology. The Comprehensive Plan recommended a County-wide approach to solid waste management with the preferred method of disposal incorporating waste reduction and recycling activities, a waste to energy facility, recycling/transfer stations and a regional residue landfill. The Plan was updated in 1992 and 1998.

System Development

The waste to energy elements, including size, site selection, energy market analysis and overall feasibility, were developed for the City and County in a Project Definition Report prepared by HDR Engineering in 1985. A Draft Environmental Impact Statement for the System was prepared based upon the State Environmental Policy Act. Public hearings were held and a Final EIS was issued in 1986. The environmental documents were challenged and the Spokane County Superior Court ruled in favor of the System on all issues.

A detailed contractor selection process commenced with the issuance of a Request for Qualifications (RFQ) in May, 1986. Sixteen responses were received, and five vendors were invited to respond to the Request for Proposals (RFP), issued in December, 1986. Four vendors' submitted proposals and Wheelabrator (formerly Signal Environmental Systems) was selected as the preferred vendor. After successful negotiations, the City and County entered into the Construction and Service Contracts with Wheelabrator Spokane Inc. in November, 1987 (Amended and Restated in 1989) for construction and operation of the waste to energy facility. A Conditional Notice to Proceed for construction of the waste to energy facility was issued on February 10, 1989. Only tasks that were of a nonpermanent nature, such as land clearing, could be performed until the last remaining permit (the Prevention of Significant Deterioration [PSD] Permit) was obtained. This permit became final on January 2, 1990, and on January 3, 1990, the Final Notice to Proceed was issued. Construction began immediately and Wheelabrator finished the project ahead of schedule. The "Burn" took place on September 5, 1991. Acceptance testing was performed on the waste to energy facility between November 8 and November 15, 1991, during which time the facility demonstrated compliance with the full acceptance standards. On February 17, 1992, the waste to energy facility was officially accepted by the City Council. Concurrent with construction of the waste to energy facility, the North County Transfer Station was constructed by Citadel; the Valley Transfer Station was constructed by Lydig; and the recycling center at the waste to energy facility was constructed by Garco. All the facilities were completed on schedule and opened to the public on December 23, 1991.

Century West Engineering was hired in mid-1987 to site and develop an ash landfill. During the Landfill Siting and Development Study, a site search identified 228 potential sites in Spokane County. Owners of 54 of these sites volunteered to have their property evaluated. This was narrowed down to 14, and ultimately the following three sites were selected for further consideration: Lance Hills, Grove Road, and Malloy Prairie. However, during the process of selecting one of these sites as the preferred site, two other options were introduced. They included out-of-county disposal via long haul at existing regional landfills and expansion of the existing Marshall Landfill. An RFP was issued and three proposals were submitted. They were from the Rabanco Regional Landfill in Klickitat County, WA; Waste Management's Landfill in Gilliam County, OR; and Finley Buttes Landfill in Morrow County, OR. The Marshall Landfill did not submit a proposal on expansion of its landfill. Ultimately it was decided that long haul was the best option and a contract was executed with Rabanco on July 26, 1991.

The last component of the System to be implemented was a regional composting facility. An RFQ/P was issued on March 31, 1992, and proposals were received from Ecocycle Composting and O. M. Scott & Sons. Scott's was selected as the preferred vendor and a contract for composting services was executed with them on July 6, 1993. A site was selected, with Scott's approval, just south of the North County Transfer Station. The Regional Compost Facility began operating in November, 1993.

In 2000, the contract with O.M. Scott was terminated. On May 23, 2000, a contract with Norcal Waste Systems, Inc. was entered into for operation of the compost facility using the Ag-Bag technology.

Financing

Pursuant to recommendations of the Comprehensive Solid Waste Management Plan 1984 Update and the Morrison-Knudsen Feasibility Study, the City of Spokane borrowed $50 million on a short-term bond anticipation note in December 1984. The timing was significant because of pending tax law changes which would become effective in January 1985. The advantage of borrowing these funds prior to January 1985 was that the interest earned over and above the interest due on these notes (arbitrage) could be used for solid waste project development. During the four-year life of these bonds, the total revenue earned from the arbitrage was approximately $4,700,000. The arbitrage funds were used to support the Spokane Regional Solid Waste Disposal Project in developing the feasibility of a waste to energy facility, the environmental review process, and procurement process. Waste reduction/recycling, school programs, litter control programs, and ash residue disposal options were also supported by these funds. Permanent long-term financing was secured in January 1989, at which time the $50 million short-term notes were paid off. The City of Spokane borrowed $105,250,000 in revenue bonds to finance the cost of acquisition and construction of the waste to energy facility, two transfer stations, recycling centers, household hazardous waste turn-in sites, and a landfill cell for disposal of bypass and non-processible materials. Spokane County received $20 million of the revenue bonds for landfill closure expenses. In addition to the revenue bonds, the System was financed by a $60 million Referendum 39 Grant from the Department of Ecology. The City Council approved acceptance of this grant on November 17, 1986, and the County Commissioners approved it on November 18, 1986. On November 24, 1986, the $60 million grant, which provided 50% matching funds for eligible expenditures, was executed.

Ash Management

Annually, Spokane's Waste to Energy (WTE) Facility processes over 300,000 tons of MSW. Steam that is generated is piped to the Turbine-Generator to generate electricity for sale. The products of combustion include bottom ash, grate siftings and fly ash. The bottom ash is material which is noncombustible, or too large to be consumed during its time on the grates. Grate siftings are small particles that fall through the grates during the combustion process. Fly ash is made up of very small particles of non-combustibles that are entrained in the flue gas and carried through the boiler gas passages. Bottom ash is transported by the furnace grates to the Ram Ash Expeller where it is quenched, dewatered and deposited on the Bottom Ash Vibrating Transfer Conveyor. Grate siftings are combined with the bottom ash in the Ram Ash Expeller. Slaked lime slurry reacts with the acid gases in the Spray Dryer Absorber (SDA). In addition to neutralizing the acid gases, this process produces a dry powder that falls to the SDA hoppers and becomes part of the fly ash. The flue gas is drawn through the Fabric Filters, and the remaining fly ash and powder is deposited on the filter bags. Periodically, a pulse of air is discharged into the bags, dislodging the collected material, which falls to the Fabric Filter hopper. The fly ash is conveyed to the Ash Conditioner and treated with phosphoric acid diluted with water, using the Wesphix process. The treated ash is a damp, dust-free material containing lime, dirt, and complex metal compounds of low solubility. The fly ash is then combined with the bottom ash and conveyed to the Ash Handling Building. At the Ash Handling Building a rotating-drum magnetic separator removes ferrous materials from the ash stream. Ferrous materials are baled and recycled on the floor. At this point the ash is either deposited in trucks or stored in the building for later removal. Approximately three days' capacity for ash storage exists in the Ash Handling Building. Reinforced concrete walls at the perimeter of the building provide 16 feet of storage depth.
The entire ash handling system is enclosed. The bottom two floors of the Boiler Building are sealed. The APC Building provides additional containment for the SDA system and Fabric Filter Modules. The conveyor galleries and Ash Handling Building are likewise enclosed.
The Regional System has executed a contract with the Regional Disposal Company (RDC) to have all combustion residues requiring disposal transported to, and disposed of, at the Rabanco

Regional Landfill in Eastern Klickitat County. This is a minimum ten-year contract with the City having the option to extend it for three successive five-year periods thereafter. Ash is top-loaded into 20-cubic-yard custom designed Intermodal Containers which are lined with Teflon and are double sealed at the rear door. The WTE Facility uses 8-15 containers per day. Each container holds approximately 30 tons of ash. The containers are hauled by truck to the Burlington Northern Yardley Intermodal Hub and are loaded onto the train for transport to the Rabanco Regional Landfill. Empty containers are returned by the same method. The WTE Facility generates approximately 93,000 tons per year of combined ash. Approximately 10,000 tons of ferrous metals each year is separated from the ash, baled and recycled.

Ash Sampling and Testing

The Spokane Regional Solid Waste System samples bottom ash, fly ash/scrubber residue, and combined ash each quarter by collecting two (2) eight-hour composite samples of each waste stream on seven consecutive days. Each of these composite samples (42 each quarter) is sampled for arsenic, barium, cadmium, lead, mercury, selenium, chromium, copper, nickel, zinc and silver by an independent testing laboratory. Once per year a quarterly composite sample will also be analyzed for dioxins and dibenzo-furans. The results of the quarterly testing are submitted to Ecology.

Endnotes:

[1] Side by side analysis of 40 CFR Part 60 Subpart Eb Verses Chapter 173-434 WAC

	40 CFR Part 60 Subpart Eb (proposed)	WAC 173-434 (current)
PM	-	67 mg/dcsm (<250 ton/dy SW)
PM	24 mg/dscm (>250 ton MSW)	46 mg/dcsm (>250 ton/dy SW)
Opacity (6 min.)	10%	10% (transmissometer)
opacity	-	5% (visual)
opacity	-	0% (visual, other than incinerator stack)
cadmium	0.020 mg/dscm	no limit
lead	0.20 mg/dscm	no limit
mercury	0.080 mg/dscm or 15% of potential	no limit
SO2 (7% O2)	30 ppmv (daily) or 20% of potential (daily)	50 ppmv (1 hr) or 20% of uncontrolled
HCL (7% O2)	25 ppm or 5% of potential	50 ppm or 20% of uncontrolled
dioxin	30 then 13 ng/dscm	no limit
NOx	180 1^{st} yr then 150 ppm	no limit
CO	50, 100, or 150 ppm, depending on combustor type	no limit

[2] This exception for cement plants is proposed in recognition of preserving the status quo. The two cement plants in Washington are not currently permitted under Chapter 434, and the applicability of Chapter 434 WAC to cement plants has not been formally established. This exception would allow cement plants to continue established operations without triggering Chapter 434. Only if a cement plants expanded the substances incinerated to that which meets the new definition of solid waste might Chapter 434 applicability be triggered. Amended Chapter 173-434 WAC

[3] "Solid waste" includes garbage, ashes, industrial wastes, swill, demolition and construction wastes, and abandoned vehicles or their parts. It can also include discharge from septic tanks and dangerous wastes.

[4] There are several types of MSW mass burn combustion systems for recovering energy from waste, including refractory and modular furnaces; but "waterwall" furnaces are the most popular at the present time. Waterwall technology is similar to the furnaces used at coal burning power plants. Exhaust gases are generally passed through a "scrubber", an "electrostatic precipitator", or a "fabric filter baghouse" in order to remove particulates such as "fly ash", and acid gases, before they are released through the stack.

[5] Tacoma Facility study: Prepared by: Appel Consultants, INC. for Western Regional Biomass Energy Program P.O. Box 95085 Lincoln NE 68509- Taken in part of larger report:
Bubbling Fluidized Bed Combustion (BFBC) at atmospheric pressure FBC in boilers at atmospheric pressure can be particularly useful for high ash coals, and/or those with variable characteristics. Relatively coarse particles at around 3 mm size are fed into the combustion chamber. Two formats are used, bubbling beds (BFBC) and circulating beds (CFBC). There was rapid growth in the coal-fired power generation capacity using FBC between 1985 and 1995, but it still represents less than 2% of the world total. Combustion takes place at temperatures from 800-900°C. Bubbling beds use a low fluidizing velocity, so that the particles are held mainly in a bed which will have a depth of about 1 m, and has a definable surface. Sand is often used to improve bed stability, together with limestone for SO_2 absorption. As the coal particles are burned away and become smaller, they are elutriated with the gases, and subsequently removed as fly ash. In-bed tubes are used to control the bed temperature and generate steam. The flue gases are normally cleaned using a cyclone, and then pass through further heat exchangers, raising steam.

Unit size

Atmospheric BFBC is mainly used for boilers up to about 25 MWe, although there are a few larger plants where it has been used to retrofit an existing unit.

Combustion takes place at temperatures from 800-900°C resulting in reduced NO_x formation compared with PCC. Air staging can further reduce NO_x formation. N_2O formation is, however, increased. SO_2 emissions can be reduced by the injection of sorbent into the bed, and the subsequent removal of ash together with reacted sorbent Limestone or dolomite are commonly used for this purpose. A disadvantage of BFBC is that in order to remove SO_2, a much higher Ca/S ratio is needed than in atmospheric CFBC. This increases costs, and in particular the cost of residues disposal.

Residues
The residues consist of the original mineral matter, most of which does not melt at the combustion temperatures used. Where sorbent is added for SO_2 removal, there will be additional CaO/MgO, $CaSO_4$ and $CaCO_3$ present. There may be a high free lime content and leachates will be strongly alkaline. Carbon-in-ash levels are higher in FBC residues that in those from PCC.

[6] Clean Coal Technology, pages 5-112 7/ 2002

[7] Bonneville Power Administration rates to PF customers at the wholesale level.12/2002

[8] Tacoma plant manager personal contact 2/20/2003

[9] The Air Quality II Conference (AQII) on mercury and fine particulates 9/2000 McLean, VA Page 4

[10] A second heat exchanger, often referred to as an economizer, is used to recover even more of the heat from the oxidized exhaust. In its simplest form, a pair of dampers works together to direct all or some of the hot exhaust from the stack to the secondary heat exchanger. Clean ambient air flows across the other side of the exchanger, heating the clean air for process or building heat. The two streams are isolated, eliminated any potential mixing, or cross contamination.

[11] See appendix A (Tacoma Steam Plant Study)

[12] See appendix B (Spokane Facility information)

[13] $50,000 per FTE average (excluding benefits)

[14] Office of Financial Management, Washington State Input Output, 1987 Study.

[15] http://www.epa.gov/airmarkets/tracking/index.html (SO2,NOx)
http://www.icfconsulting.com/News_&_Events/usnox_2003_projections.asp Kyoto Protocol - Tradable Emission Reduction Credits (CO) 2/27/2003
*please note that values are for Eastern US trading units

[16] Response to determination of application of Chapter 173-434 WAC and petition for variance by the City of Tacoma Public Works Department for the City of Tacoma Steam Plant before the Puget Sound Clean Air Agency, 1/18/2001 page 23

[17] Modeling and monitoring records in file, 3/6/2003

[18] personal conversation with Laurie Hannan, 12/2002

[19] Wood Waste 4,500 BTU/lbs, Creosote Ties 7,000 BTU/lbs

[20] Cost supplied by the facility, 11/02

[21] http://www.beyondpesticides.org/WOOD/creosote_petition.htm

[22] http://composites.wsu.edu/navy/Navy1/Presentations/PendletonPoleConf.pdf

[23] state of Washington Department of Ecology, order #DE 95AQ-I026, page 4 line 16

[24] state of Washington ECY Solid Waste section, pub 0107-115,calculated by writer 11/18/02

Appendix 2:

Supplemental memorandum addressing only the amendments impacting the cement manufacturing industry

MEMORANDUM

December 5, 2003

TO: The Rule Making File for WAC 173-434-030

FROM: Cathy Carruthers, Economic and Regulatory Research

SUBJECT: The rule amendment creating an exemption for cement manufacturers

This memo reviews the economic impact of the cement manufacturing amendment.

> *WAC 173-434-030 (3)(b) "… solid waste does not include: … (b) At a Portland cement plant, (i) Tires; and (ii) waste oil that is non-hazardous as defined by WAC 173-303-515, Standards for the Management of Used Oil."*

Determination

The rule amendment creating an exemption for the cement manufacturers has been reviewed. Evidence indicates that the probable benefits exceed the probable costs as required under RCW 34.05.328. Further, the exemption is designed to reduce the burden of the rule for those who are required to comply. This constitutes cost minimization under Chapter 19.85 RCW and creates a less burdensome rule under RCW 34.05.328.

Background for the Determination

The rule currently applies to cement manufacturing plants and would not allow them to burn as much solid waste (tires and waste oil) as they are currently permitted to burn under their PSCAA[1] permits. There are two plants in Seattle Washington, LaFarge and Ash Grove, which have both requested an exemption. They burn tires and waste oil as a replacement fuel.

Cement Manufacturing	
	Code
NAICS	327320
SIC	3273

The cement manufacturing plants are large employers and have been burning tires and waste oil under PSCAA permits for several years.[2] The plants requested the exemption because of the potential losses they expect they would experience. The plants were unaware that they needed to comply with this rule. Without this amendment the permits which the plants rely on for compliance could be more constrained than they currently are for particulates, SO_2, and HCl.

The cement manufacturer part of the amendment exempts tires and waste oil fuels, which they are currently permitted to burn under their existing PSCAA permits.
The exemption would generate benefits in the form of:

(1) cost reductions from reduced expenditures on fuel and revenues from tipping fees for the cement plants,
(2) reduced landfilling for the wastes.

[1] Puget Sound Clean Air Agency.
[2] PSCAA inspection reports.

The exemption may generate health costs because under the current rule the plants might have been further restricted in their emissions of particulates, SO_2, and HCl. In addition Ecology will have to submit a Relaxation Analysis to EPA[3] for approval.

Detail on the benefits:

The primary benefit is a cost savings to the cement manufacturers. The present value of the savings to the companies, over a 20 year period, is in the tens of millions.[4] A cost reduction is due to maintaining the following existing gains:[5]

- reduced expenditures on fuel
- tipping fees for the solid waste that forms the replacement fuel

The companies have already modified their plants and are running, while using the replacement fuels listed in their permits. The exemption saves the companies any losses that would be associated with any premature removal of capital or additions of capital to adjust for a shift in the fuel mix.

Finally, there may be some gain to the state from reduced landfilling. This benefit would accrue in so far as (1) tipping fees do not cover both the private and societal costs of landfills and (2) there was no alternative market for the solid waste. The wastes do seem to have other markets for disposal. Thus this is a small benefit by comparison to the primary benefit. Therefore this analysis does not rely on this potential gain.

Detail on the costs:

The primary potential costs may be health related. Health may be affected if enforcing compliance with the existing rule would have positive health effects. Ecology has reviewed the potential health effects of the emission limits that would apply to the two plants given their current activities. Without the exemption, the companies might have had to reduce their particulate, SO_2 and HCl emissions if they continued incinerating tires and waste oil.

The exemption would allow the two existing cement plants to comply under their existing permits. These permits are based on other rules and allow burning of the fuels that they currently burn. Ecology modeled the emissions of the two stacks. The purpose of the modeling was to review the revised constraints between the existing limits in the rule and the limits in the current permits, which allow burning of tires and waste oil.[6]

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[3] Environmental Protection Agency

[4] Actual dollar values are suppressed for this document. Under "RCW 42.17.31908, Business information gathered under certain regulatory activities exempt", public disclosure requirements do not apply to information gathered under chapter 19.85 RCW or RCW 34.05.328 that can be identified to a particular business. Given that there are only two cement manufacturers and 2 suppliers willing to provide information, each of the cement companies would know exactly what the other competitor and suppliers had given Ecology, if the dollar values are given. The data was given with the understanding that it would be protected to the extent feasible under RCW 42.17.31908.

[5] Ash Grove's permit allows burning of whole tires, greases and oils. They are allowed to burn up to 30% tires by weight. LaFarge is allowed to replace up to 25% of the heat input of its fossil fuel with replacement fuel, up to 20% of its fossil fuels with tires and up to 10% of its Coke (coal) with Tank Bottom Oil.

[6] Ecology requested data that would allow calculation of an emissions shift from both the companies but the data was not provided in time for the modeling effort.

For SO_2 and HCl, the stacks are high and the concentration of the emissions is reduced through mixing before exposure occurs. Modeling indicates that under the current permits the concentrations of SO_2 and HCl drop to a point where risk assessment cannot conclude there is a health effect. Note, that this is not a conclusion of no health effect, but that the health effect, if it exists, cannot be determined.

Particulate changes cannot be estimated.

> "For Particulate Matter, the regulatory parameters in 434 or the next most stringent rule cannot be translated into ambient concentrations. Without ambient concentrations, potential exposure and health effects cannot be calculated. It is not then possible to say whether there would or would not be a change in health effect from exposure to particulate matter with a change in the rule. Comparison of requirements under 434 and Regulation I, section 9.09 regarding PM shows that 0.02 grains/dscf @ stand. cond. 7% Oxygen, will go to 0.05 gr/dscf (no Oxygen correction). This is a reduction in the constraint on PM and would not be likely to create a beneficial health effect."[7]

Given that we don't know the effect on ambient PM concentrations, other than to say standard relaxation cannot be beneficial, a health effect from particulates may exist but it cannot be estimated. If there is a potential cost it is an uncertain one. WAC 173-434 only constrains concentrations of particulates and not total magnitudes of exposure. Thus it is not clear that WAC 173-434 creates a constraint on health effects for the long run.

Particulates generate health costs due to acute and chronic disease and conditions such as: asthma, bronchitis, COPD, pneumonia, ischemic heart disease, and congestive heart failure. In some acute cases early mortality may result. Care and costs may range from episodic to long term. The cost per case of asthma may range from an average case at $12,000 to a severe case at $220,000.[8] The value of hospitalization for bronchitis, COPD, pneumonia, ischemic heart disease, and congestive heart failure ranges averages from $8,000 to $15,000.[9] It is important to note that the willingness to pay values for avoidance of such conditions, are likely to be higher than the cost based estimate of the value of the condition. The value of a statistical life is large and ranges from $1 to $16 million depending on who is affected.[10]

Ecology cannot estimate the particulate health impact. It is only possible to say that multiple cases of each condition, or 4 early mortalities directly caused by a particulate emissions increase (if any), would be required to generate net costs. This is not very likely.

Ecology expects to incur costs associated with filing a Relaxation Analysis with EPA. The EPA will revise its federal adoption of the existing rule if the Relaxation Analysis is sufficient. For Ecology it requires less than 0.1 FTE.[11] The companies themselves will be asked to provide the reports for the Relaxation Analysis. The high end expected costs based on past work provided by other companies is $30,000.[12]

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[7] See Appendix A.
[8] EPA, Cost of Illness Handbook, Section IV.
[9] Values indexed to 2003 from Appendix 1 of the 812 Retrospective Report, EPA
[10] For a discussion of the literature see: Cost Benefit Analysis, Richard Layard and Stephen Glaister, Cambridge University Press, 1994; and W. Kip Viscusi "The Value of Risks to Life and Health" J. of Econ. Lit. Vol 31 Dec. 1993. a survey of the literature. Viscusi is also in: Journal of Risk and Uncertainty Vol 8 No 1 1994 reprinted by Kluwer Academic Publishers which has a large set of articles with arguments on values from both sides. See also, EPA Guidelines for Preparing Economic Analyses, Pg. 87, which gives a value of $5 million.
[11] Full time equivalent of less than 10% time for person for one year.
[12] Steve Cross, based on two recent analyses submitted by companies.

Time Frame:

This analysis uses a 20 year time period to estimate the relative costs and benefits. Discounting is based on a 3% real social rate of time preference.[13]

Probable net benefits:

There is some certainty regarding the benefits of this rule to industry and uncertainty regarding the health benefits and costs. Given that there are known revenue gains and fuel savings to the cement plants from the additional amendment, and given that the potential but unknown health costs can be limited under either an existing permit or under other rules, it is likely that the benefits of the cement plant exemption exceed the costs. Taken together, the information above gives Ecology the basis for the determination, that, the probable benefits exceed the probable costs.

	Industry	Health	Landfills
Certainty?	Wide Range of Values	Uncertain Magnitude	Uncertain Magnitude
Benefits	Tens of millions over a 20 year period		If tipping fees do not incorporate social costs and there is no market for the waste.
Costs		SO2, HCl, Particulates	

Least Burden and Alternatives Considered

The three Portland Cement alternatives considered were:

1. No change to the existing rule.

   The existing rule was used as a basis for comparison for the Portland Cement amendment.

2. An amendment that would allow burning of other solid wastes.

   It was not possible to determine whether burning of additional solid wastes would be viable. There was no data available on either the expected net gain to the companies or the emissions shift that would be created. Ecology needed to have the emissions data in time to do appropriate modeling. Without the data, it was not possible to determine either costs or benefits.

3. The Portland Cement amendment considered above in this Memo, allows the companies to retain their current permits for the burning of tires and waste oil.

   This version of the rule is less burdensome than the existing rule for the cement plants. Further it is likely that it generates net benefits.

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[13] The investment decision for plant modifications has already been made. The investment is a sunk cost. Without the amendment there would be a loss of both an existing flow of revenues and an existing stream of cost savings. There is no indication that the plants invest all of this gain. Thus, a substantial share of it would be assumed to go to consumption through wages and payments. Therefore Ecology is using the Social Rate of Time Preference for discounting the gain. See Appendix B.

Appendix A:

Commentary on Predicted Ambient levels of SO_2 and HCl with Respect to Health Effect Relative to Relaxing the Limits of 434 to the Washington Standards

Commentary on Predicted Ambient levels of SO_2 and HCl with Respect to Health Effect Relative to Relaxing the Limits of 434 to the Washington Standards

by

Harriet Ammann

03 November 2003

For SO_2, Ash Grove appears to be covered by their PSD permit, which limits them without regard to 434. The permitted level of 156 g/s produces a maximum modeled one-hour concentration of 290 $\mu g/m^3$ which is well below the modeled threshold of 1040 $\mu g/m^3$ (Clint Bowmen 2003) so that no health impacts can be demonstrated by not using 434.

Lafarge is not permitted under PSD, but would be subject to the Washington State Standard of 1000 ppm in-stack concentration (at 127.4 g/s), which yields 990 $\mu g/m^3$ on the high ground to the west and southwest of the facility. This is less than the health based threshold of 1040 $\mu g/m^3$ (Clint Bowman 2003). No health effects could be demonstrated from not using 434.

For HCl, the maximum 24-hour concentration calculated from Ash Grove emissions will be 36 $\mu g/m^3$. For Lafarge, a similar calculation would predict a 24-hour maximum concentration of 22 $\mu g/m^3$ (Clint Bowman 2003). The U.S.EPA IRIS Reference Concentration (RfC) is 0.02 mg/m^3 or 20 $\mu g/m^3$. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfC does not define at what exposures above the RfC health impacts could occur. It is not possible to demonstrate a real difference in toxicological or health impacts among 20, 22, or 36 $\mu g/m^3$ ambient exposure. One cannot therefore say that the predicted exposures are likely to have an impact on health, and one can conclude that there would not be a measurable effect on health from HCl from not using 434.

For Particulate Matter, the regulatory parameters in 434 or the next most stringent rule cannot be translated into ambient concentrations. Without ambient concentrations, potential exposure and health effects cannot be calculated. It is not then possible to say whether there would or would not be a change in health effect from exposure to particulate matter with a change in the rule. Comparison of requirements under 434 and Regulation I, section 9.09 regarding PM shows that 0.02 grains/dscf @ stand. cond. 7% Oxygen, will go to 0.05 gr/dscf (no Oxygen correction). This is a reduction in the constraint on PM and would not be likely to create a beneficial health effect.

Appendix B:

Social Rate of Time Preference

April 24, 2003

TO: The File
FROM: Cathy Carruthers
SUBJECT: Social Rate of Time Preference (SRTP)

The social rate of time preference used to discount pure consumption tradeoffs over time is much discussed in the literature. This memo lays out a method for handling two issues.

1. When do we use a general SRTP?
2. What is the SRTP?
3. What do we do about discounting when there is a mix of consumption dollars and investment dollars.
4. How do we handle risk?

Using the SRTP:

The analyst can use a different rate when there is an indication that a different rate should be used.
Example 1: if the rule will require and affect investment only and will not generate any consumption benefits, then an investment related interest rate could be used.
Example 2: the I bond rate below is for 30 year bonds. It is possible that a different interest rate should be used when the consumption shift takes place in a very short time.

The SRTP ≈ 2.9%:

The best indication of risk free, inflation adjusted SRTP for regulatory work would be an inflation adjusted government security. The table below indicates the range of rates for I Bonds[14] over the last 5 years, where bonds are purchased directly from the Department of Treasury. This would tend to indicate the SRTP for this period ranges between 1.6% and 3.6% with an average rate of 2.9%.

[14] http://www.publicdebt.treas.gov/sav/sbirate2.htm

Department of Treasury Data on I Bond Rates					
			INFLATION	Annual	Return on
DATE	FIXED RATES*	DATE	RATES*	Inflation	I Bonds
1-Nov-02	1.60%	1-Nov-02	1.23%	1.51%	4.08%
1-May-02	2.00%	1-May-02	0.28%		2.56%
1-Nov-01	2.00%	1-Nov-01	1.19%	2.65%	4.39%
1-May-01	3.00%	1-May-01	1.44%		5.90%
1-Nov-00	3.40%	1-Nov-00	1.52%	3.46%	6.46%
1-May-00	3.60%	1-May-00	1.91%		7.46%
1-Nov-99	3.40%	1-Nov-99	1.76%	2.64%	6.95%
1-May-99	3.30%	1-May-99	0.86%		5.03%
1-Nov-98	3.30%	1-Nov-98	0.86%	1.49%	5.03%
1-Sep-98	3.40%	1-Sep-98	0.62%		4.64%
		*semiannual rates			
Mean Rate	2.90%			2.35%	5.25%

Mixed consumption and investment rates without risk:

The following formula will allow the foregone consumption due to reduced investment to be factored into present value calculations.

$$\sum_{t=0,n} \frac{k_t}{(1+s)^t} = \frac{k(1+s)}{s}$$

Where k_t is return on capital in time t and s is the social rate of time preference and n is infinite, this yields the following multipliers for year 0 investment requirements in a rule.

Return on capital	Multiplier using SRTP
5%	1.77
6%	2.13
7%	2.48
8%	2.84
9%	3.19
10%	3.55
11%	3.90
12%	4.26
13%	4.61
14%	4.97
15%	5.32
16%	5.68
17%	6.03
18%	6.39
19%	6.74
20%	7.10

If the expected time horizon for reinvestment is not long the formula could be substituted for the table.

Corporate bonds for a sector, with ratings of AAA could generally be regarded as relatively risk free.

Risk that the expected environmental result will not occur:

Interest rates used to be adjusted to reflect probable risk. Risk of failure of environmental investment (such as a lack of and expected impact on a fishery) should be modeled directly by using ranges rather than through imbedding risk in the interest rate. This is now easy to do using a Monte Carlo or other sensitivity test.