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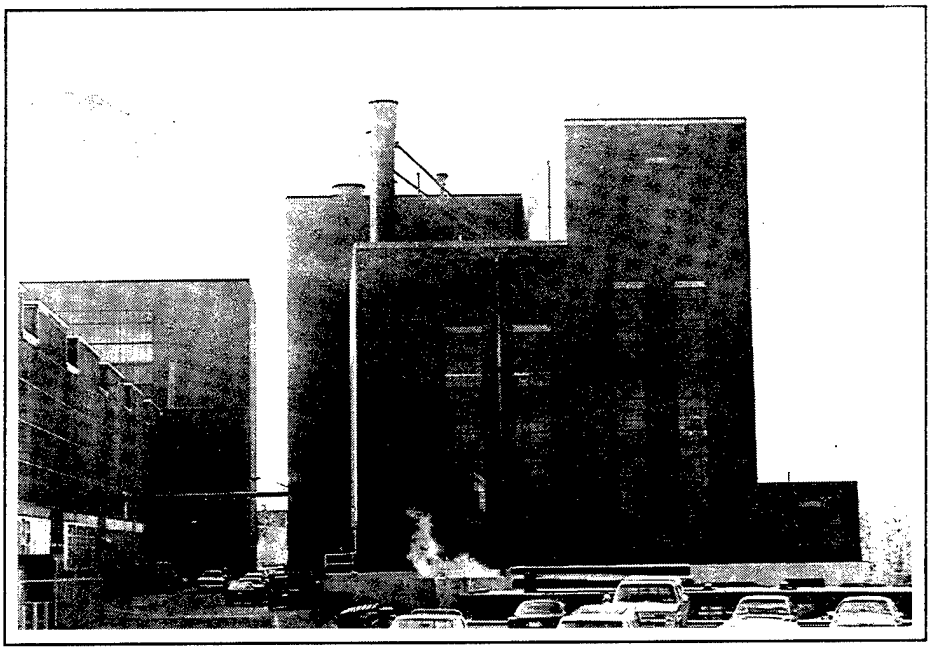
Central Heating Plant Modernization Study for Watervliet Arsenal, New York

by
Martin J. Savoie and Thomas E. Durbin



The central heating plant (CHP) at Watervliet Arsenal, NY contains five boilers, two of which are 42 years old, two 40 years old, and one 17 years old. The age of this equipment warranted an investigation of alternatives for providing thermal energy for this facility. Watervliet Arsenal requested the U.S. Army Construction Engineering Research Laboratories (USACERL) to perform a study to determine the most viable options available to provide energy for the coming years. This study determined the status of the CHP, and identified and evaluated (both technically and economically) options for meeting current and future thermal energy needs at WVA. Two alternatives were recommended: (1) installation of a new natural gas fired plant with cogeneration, which has the lowest life-cycle costs (LCC) based on a 25-year facility life, or (2) installation of new gas/oil boilers in the existing facility, which has a larger LCC, but lower initial investment costs, than the first recommended alternative.

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The central heating plant (CHP) at Watervliet Arsenal, NY contains five boilers, two of which are 42 years old, two 40 years old, and one 17 years old. The age of this equipment warranted an investigation of alternatives for providing thermal energy for this facility. Watervliet Arsenal requested the U.S. Army Construction Engineering Research Laboratories (USACERL) to perform a study to determine the most viable options available to provide energy for the coming years. This study determined the status of the CHP, and identified and evaluated (both technically and economically) options for meeting current and future thermal energy needs at WVA. Two alternatives were recommended: (1) installation of a new natural gas fired plant with cogeneration, which has the lowest life-cycle costs (LCC) based on a 25-year facility life, or (2) installation of new gas/oil boilers in the existing facility, which has a larger LCC, but lower initial investment costs, than the first recommended alternative.

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Foreword

This study was conducted for Watervliet Arsenal under Military Interdepartmental Purchase Request (MIPR) No. W16H1F-3-79. The technical monitor was Philip Darcy, SMCWV-ATD.

The work was performed by the Utilities Division (UL-U) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Thomas E. Durbin. Martin J. Savoie is Chief, CECER-UL-U; and John T. Bandy is Operations Chief, CECER-UL. The USACERL technical editor was William J. Wolfe, Technical Resources Center.

COL James T. Scott is Commander of USACERL, and Dr. Michael J. O'Connor is Director.

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1 Introduction

Background

Watervliet Arsenal (WVA), established in 1813, specializes in the manufacture of cannons and gun tubes (barrels). Items produced at WVA originally included fuses, rockets, percussion caps, sponges, and gun carriages. WVA also worked to store and repair material. WVA thrived during the production "boom" of wartimes and managed to survive times of decreased production between wars and during military downsizing. WVA's manufacturing progressed with improvements in manufacturing technologies and today is a vital part of the Department of Defense (DOD). WVA supplies large caliber weapons to both U.S. and allied forces.

WVA is currently investigating modernization opportunities for the WVA Central Heating Plant (CHP). The CHP contains five boilers; two are 42 years old, two are 40 years old, and one is 17 years old. The age of this equipment warranted an investigation of alternatives for providing thermal energy for this facility. Increasing electrical costs have made cogeneration one potential alternative for modernizing the CHP. Watervliet Arsenal requested the U.S. Army Construction Engineering Research Laboratories (USACERL) to perform a study to determine the most viable options available to provide energy for the coming years.

Objectives

The objectives of this study were to determine the status of the CHP and to identify and evaluate (both technically and economically) options for meeting current and future thermal energy needs at WVA.

Approach

Past studies and operating records were analyzed to establish baseline conditions. A visual inspection of the CHP equipment was conducted to assess baseline operating conditions and problem areas.

The energy use patterns for WVA were analyzed for current thermal and electrical energy demand, heating load, and usage patterns. The future energy use for the facility was projected. Potential thermal energy supply options were then identified based on the energy use pattern analyses. These options were evaluated in terms of capital cost, operating cost, efficiency, and reliability. The evaluation also considered regionally available and appropriate fuel supplies. The life-cycle cost analyses were developed based on the study findings for maintaining the status quo, installing new boilers, and building a new plant.

Scope

The evaluation methods developed for the analysis and assessment of thermal and electrical requirements will be useful to many other installations, particularly those with central heating or power plants.

2 Existing Steam Supply Systems

Central Heating Plant

The WVA CHP, Building 136, was constructed in 1952. The two 50,000 lb/hr coal-fired, field-erected boilers originally installed at the plant produced 135 psig steam. However, the coal-firing systems were not used. These two boilers (#1 and #2) were converted to fire No. 6 oil, and a 400,000-gal oil storage tank was installed. In 1956, the building was expanded and two 110,000 lb/hr, oil-fired, water-tube boilers (#3 and #4) were added to the facility. Boiler 5, an oil-fired, 20,000 lb/hr, fire-tube boiler was installed in the plant in 1978. All five boilers are currently in operating condition and are fired with #2 oil. Boilers 1 and 2 are only operated in emergency situations with a maximum firing rate of 35,000 lb/hr. Boilers 3 and 4 are being retrofitted with gas-firing equipment and will primarily use natural gas for fuel. The installation of a low-NOx demonstration boiler to replace boiler #4 is currently being considered. Table 1 includes CHP boiler information.

Additionally, a gas-fired, 20,000 lb/hr, fire-tube boiler (#6) is housed in building 36. Boiler 6 is used to supply process steam during the summer months when the CHP is not operated. Table 2 lists information about Boiler 6. The installation of a natural gas pipeline to the CHP was begun in 1994. Both boilers 3 and 4 will burn natural gas as a primary fuel, reducing NOx emissions and essentially eliminating SOx emissions. There may be a boiler demonstration project at WVA that will provide the CHP with a new natural gas boiler equipped with a low-NOx burner to replace Boiler 4.

Though aging, the CHP is generally in good condition. The equipment has been well maintained, but much of the equipment is approaching the end of the typical useful

Table 1. Central heating plant boiler data.

Boilers	Manufacturer	Year Built	Type	Capacity (lb/hr)
1 and 2	Erie City	1952	Coal fired, converted to No. 6 fuel oil fired, retrofitted to burn No. 2 fuel oil and natural gas	50,000
3 and 4	Union Iron Works	1956	No. 6 fuel oil fired, later converted to No. 2 fuel oil fired, retrofitted for natural gas firing	110,000
5	Trane	1978	No. 6 fuel oil fired	20,000

life. The asbestos piping insulation has been removed from the CHP. The previous asbestos removal project is important because it eliminates a significant cost and safety hazard as well as reduces the time necessary to implement the CHP modernization plan.

Table 2. Boiler 6 data.

Boiler:	6
Manufacturer:	Cleaver Brooks
Year built:	1984
Type:	Natural gas fired
Capacity:	20,000 lbs/hr

Steam Distribution System

The CHP provides steam for heating through a system of belowground and overhead steam pipes. The pipes are run aboveground through buildings and underground outside of buildings. The steam is distributed at 135 psig to 38 buildings. Condensate is pumped back to the CHP through a condensate return system that parallels the steam system. Steam system losses are indicated by the quantity of water added (or made-up) to the system. The system makeup water replaces live steam losses and condensate losses in places where the condensate is contaminated. Figure 1 shows boiler water makeup for 1993. The system makeup follows steam load, as expected. The Central Energy Plant and steam system are shut down in the summer months. Boiler 6, in Building 36, provides process steam for manufacturing systems from late April to early October.

Makeup water use, as a percentage of steam flow, varies from 17.8 to 44.6 percent in the winter and from 20.8 to 52.2 percent in the spring and fall. The higher percentage of makeup in the spring and fall is due to the constant losses along the distribution system and the relatively lower quantity of steam produced. Condensate returns in excess of 80 percent (below 20 percent makeup) for central systems of this type indicate that a system is in good condition and is operated properly with condensate being returned where possible. The higher percentage of makeup water being used at WVA is partially due to the fact that some of the steam is contaminated in manufacturing processes and must be sent to the water treatment facility instead of being returned to the CHP in the form of condensate. Also, the high makeup percentage indicates that there may be significant leaks in some of the steam valves and traps in the system.

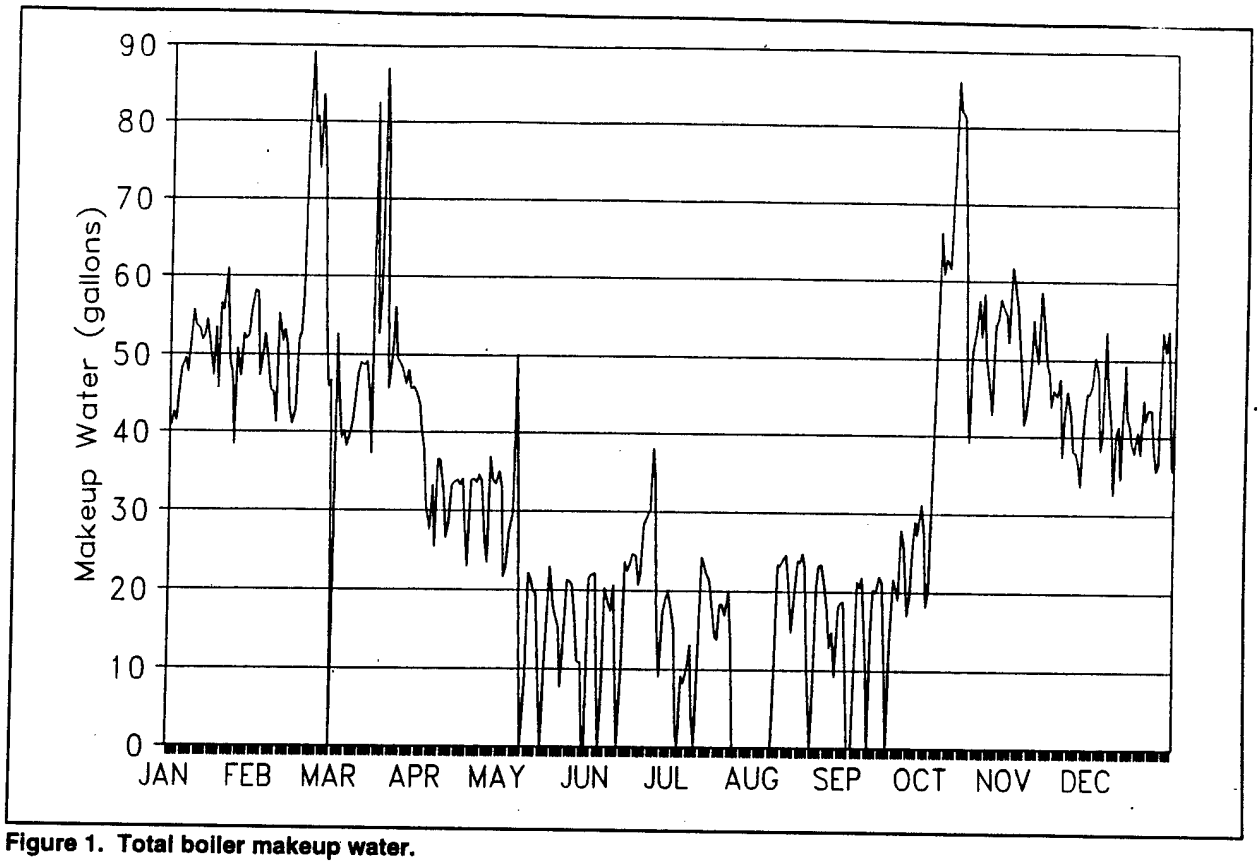

Figure 1. Total boiler makeup water.

3 Thermal Energy Supply and Consumption

This chapter describes current thermal energy supply and use at Watervliet Arsenal. The CHP steam production and fuel consumption were analyzed for trends and building heating loads, and distribution systems losses were modeled. Correlations between thermal energy use and heating degree days were developed to model energy use.

CHP Steam Production

The CHP steam production was taken from the 1993 boiler logs. The boiler logs give the steam flow for each boiler, total steam produced, fuel used, and makeup water used. Figure 2 shows the steam load profile (lb/hr) for 1993. The daily average steam load for the plant varied from a high of 82,504 lb/hr in January to low loads of approximately 20,000 lb/hr in April and October, at the end and beginning of the heating season. (The plant is shut down in April or May and restarted in October when building heating is required.) Boiler 6 is operated during the summer months to supply process steam. Figure 3 shows the plant energy output in million Btu/hr instead of lb/hr as in Figure 2.

Steam End Use

The CHP output is a good indicator of current thermal energy use, but individual building loads were estimated to determine the efficiency of the existing distribution system. There are currently no operating steam meters to measure individual building heating or process loads. End user loads were estimated using modeling techniques.

The HEATLOAD program was used to estimate the steam loads. HEATLOAD was developed by USACERL to provide a simple method of calculating building heat requirements. Other computer programs such as BLAST or DOE2 can provide more accurate analyses, but require much more detailed information to develop a reliable heat load estimate. Experience with HEATLOAD has shown it to be quite accurate

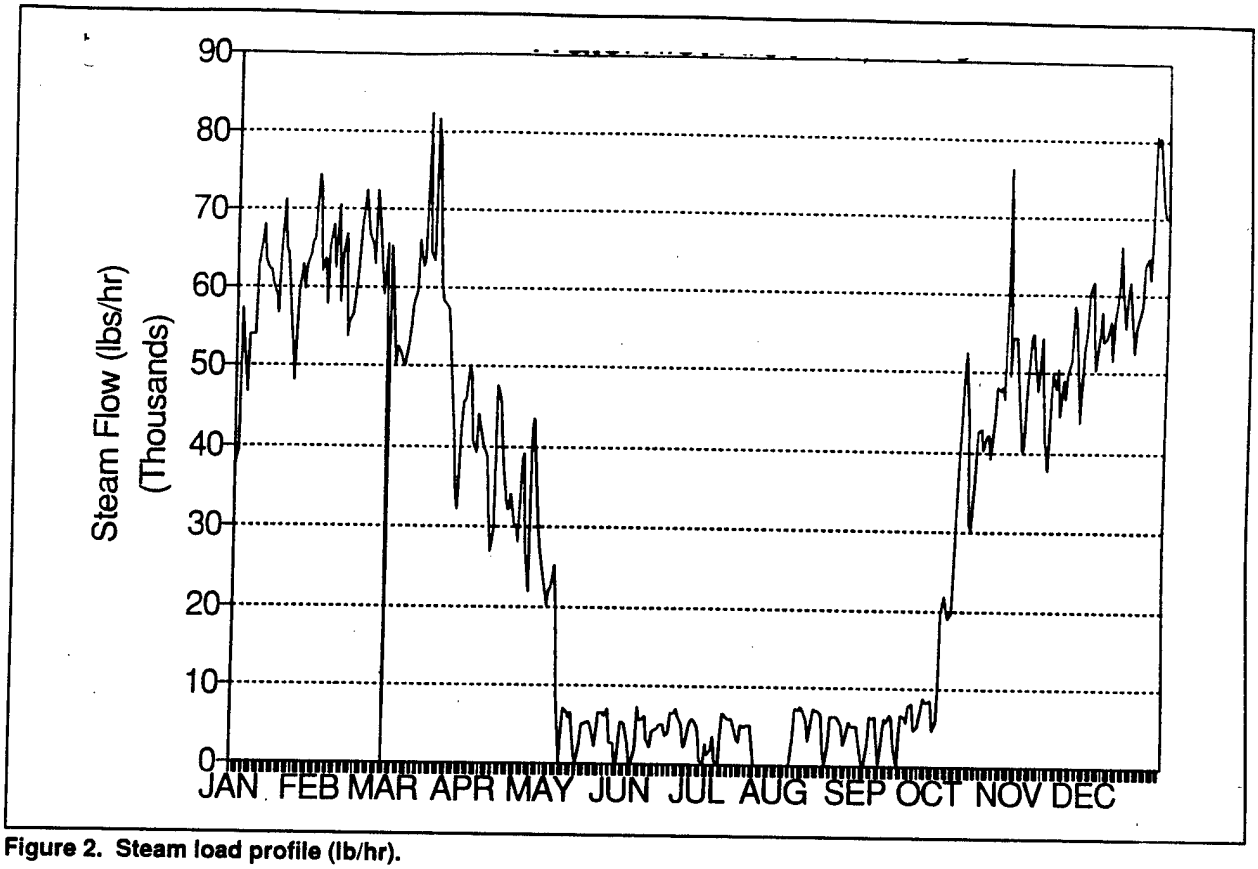

Figure 2. Steam load profile (lb/hr).

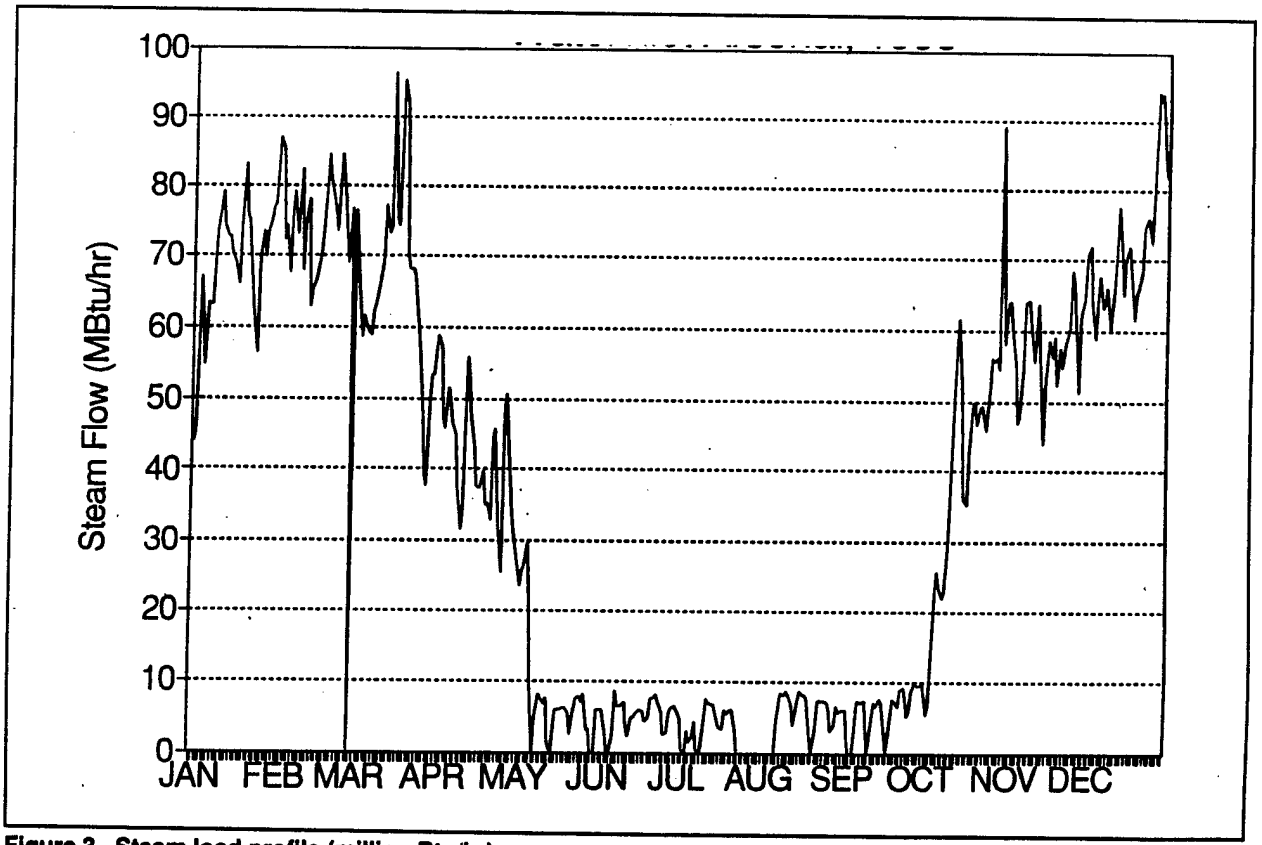

Figure 3. Steam load profile (million Btu/hr).

for estimating installation-wide building heat requirements for central energy plant load modeling.

HEATLOAD is based on a series of linear regressions developed from heating use measurements at typical facilities on several Army installations. The facility categories and corresponding daily heating energy consumption equation takes the form:

$$E_h = a_1 + (b_1 \times HDD_d) \quad \text{[Eq 1]}$$

where:

E_h = daily heating degree

a_1 = a constant representing energy usage that occurs for zero heating degree days (HDD) and reflects nonheating loads such as hot water and cooking

b_1 = the heating load parameter.

Building categories and area (sq ft) were obtained from the master planning files. Table 3 lists the parameters used for buildings at WVA.

The climatological data required for HEATLOAD, such as the historical average HDD and the design temperature, were obtained from the Army Technical Manual *Engineering Weather Data* (TM 5.785, 1978) or directly from the USAF Environmental Technical Applications Center (ETAC) at Scott AFB, IL. With this information, HEATLOAD will calculate the peak hourly heating load, average monthly loads, maximum monthly loads, and total annual heating load. Table 4 shows the total monthly steam loads estimated from steam consumption data. The individual building loads were estimated based on 1993 heating degree days and summed for each month. Table 5

Table 3. Building categories and energy consumption.

Building	Consumption
Administration/Training	$E_h = 75.71 + (7.02 \times HDD_d)$
Family Housing	$E_h = 113.50 + (10.50 \times HDD_d)$
Dining	$E_h = 241.90 + (0 \times HDD_d)$
Storage/Warehouse	$E_h = 35.70 + (10.53 \times HDD_d)$
Production/Maintenance	$E_h = 138.25 + (10.53 \times HDD_d)$
Fieldhouse/Gymnasiums	$E_h = 73.69 + (4.39 \times HDD_d)$

Table 4. Estimated monthly steam loads.

Month	Heatload (Million Btu)
January	43,699
February	43,293
March	41,880
April	26,258
May	5,717
June	3,166
July	1,941
August	3,004
September	3,509
October	25,904
November	35,545
December	45,544

gives the estimated building heating loads for the individual buildings at WVA.

Heating loads are typically very closely related to the outside temperature. A single year is not always a good prediction of the steam demand for the 25-year period required for life-cycle cost analysis of alternatives unless it is very close to the normal year. A correlation developed between steam demand and heating degree days (HDD) for 1 year can be used to project the steam demand for the life of the study period. Linear regressions were performed on the load profiles and the corresponding HDD. The monthly HDD from 1946 to 1992 were obtained from USAFETAC. Table 6 lists the long-term average monthly HDD data.

Figure 4 shows the linear regression of steam production (MBtu/hr) and heating degree days (HDD). Figure 5 reveals the relationship between steam production in MBtu (daily) and HDD. This includes the total heat in the steam plant output (not just the heat of vaporization).

A steam distribution system typically consists of steam generators, piping, regulators, valves, and steam traps. Steam enters the system at the steam plant, passes through the piping and valves, and is delivered to the buildings. The steam loses heat through the piping walls by conduction. As the steam passes through the piping and valves, the pressure decreases due to the friction of the steam with the pipe wall and fittings. Condensate forms in the piping as the steam condenses and is removed through the steam traps. The quantity of energy lost through the steam distribution system can be substantial.

Table 5. Estimated building heat loads.

Building Number	Square Footage	Yearly Heat Load (Million Btu)	Average Heat Load (Million Btu/hr)
1	13,666	1,531	0.39
2	9,828	1,101	0.28
3	9,740	1,091	0.28
4	14,000	1,568	0.40
6	15,970	1,789	0.46
8	11,173	1,252	0.32
9	4,338	486	0.12
10	66,867	5,004	1.29
15	22,990	2,788	0.69
17	7,714	935	0.23
19	9,208	1,032	0.27
20	107,157	12,994	3.20
21	17,711	1,564	0.18
22	9,955	1,207	0.30
23	21,527	2,610	0.64
24	11,876	889	0.23
25	185,850	22,537	5.56
35	336,381	28,200	8.62
36	6,293	763	0.19
38	29,400	2,465	0.75
40	182,488	13,656	3.51
41	5,023	443	0.05
44	61,009	4,565	1.17
110	208,574	25,293	6.23
112	8,355	700	0.21
114	4,888	410	0.13
115	52,072	4,365	1.33
116	2,320	194	0.06
120	101,975	12,366	3.05
121	6,445	540	0.17
122	1,552	130	0.04
123	8,262	693	0.21
124	13,199	1,107	0.34
125	119,200	14,455	3.56
126	6,614	554	0.17
130	30,904	2,591	0.79
133	7,200	604	0.18
135	190,616	23,115	5.70

The heat lost in the distribution system can be estimated by comparing the user steam needs predicted by HEATLOAD and the actual steam production data from the CHP records. The predicted steam demand and the actual steam production (MBtu/hr) data are plotted in Figure 6. The HEATLOAD prediction does not include steam system losses or condensate losses. Figure 7 shows the heat lost due to steam and condensate loss, seen as makeup water use in the CHP, and added to the HEATLOAD model. The energy use model, based on HEATLOAD values and makeup water use, closely agrees with actual steam production reported by WVA. The difference in the curves was attributed to conduction and convection losses from the steam and condensate system. Figure 8 shows a similar relationship between the model and actual steam flow curves in MBtu (daily).

Table 6. Average monthly heating degree days.

Month	HDD
January	1332
February	1180
March	954
April	543
May	219
June	9
July	0
August	0
September	114
October	444
November	757
December	1172

Previously, makeup water use, as a percentage of steam produced, was reported to vary from 17.8 to 44.6 percent in the winter and from 20.8 to 52.2 percent in the spring and fall. The data in Figure 7 show that, for a day with 28 HDD, the steam flow would average 50 MBtu/hr; the HEATLOAD estimates the building steam demand to be 30 MBtu/hr, resulting in a loss of 20 MBtu/hr (40 percent). This falls within the range previously determined for distribution system losses. Some of the heat loss in the distribution system was attributed to intentional dumping of contaminated condensate, but the rest of the losses must be attributed to leaks in traps, valves, and pipes, and conductive and convective heat loss. It would be beneficial to determine the amount of condensate/steam intentionally dumped due to contamination so that the losses attributable to leaks and conduction/convection could be accurately determined. Again, makeup water use/heat loss under 20 percent indicates that a system is in very good condition. Losses as high as 30 percent are not uncommon, but higher losses indicate a need for some system repairs. It is possible that the system is in good condition, but additional condensate dumping data must be collected before the status of distribution system can be confirmed.

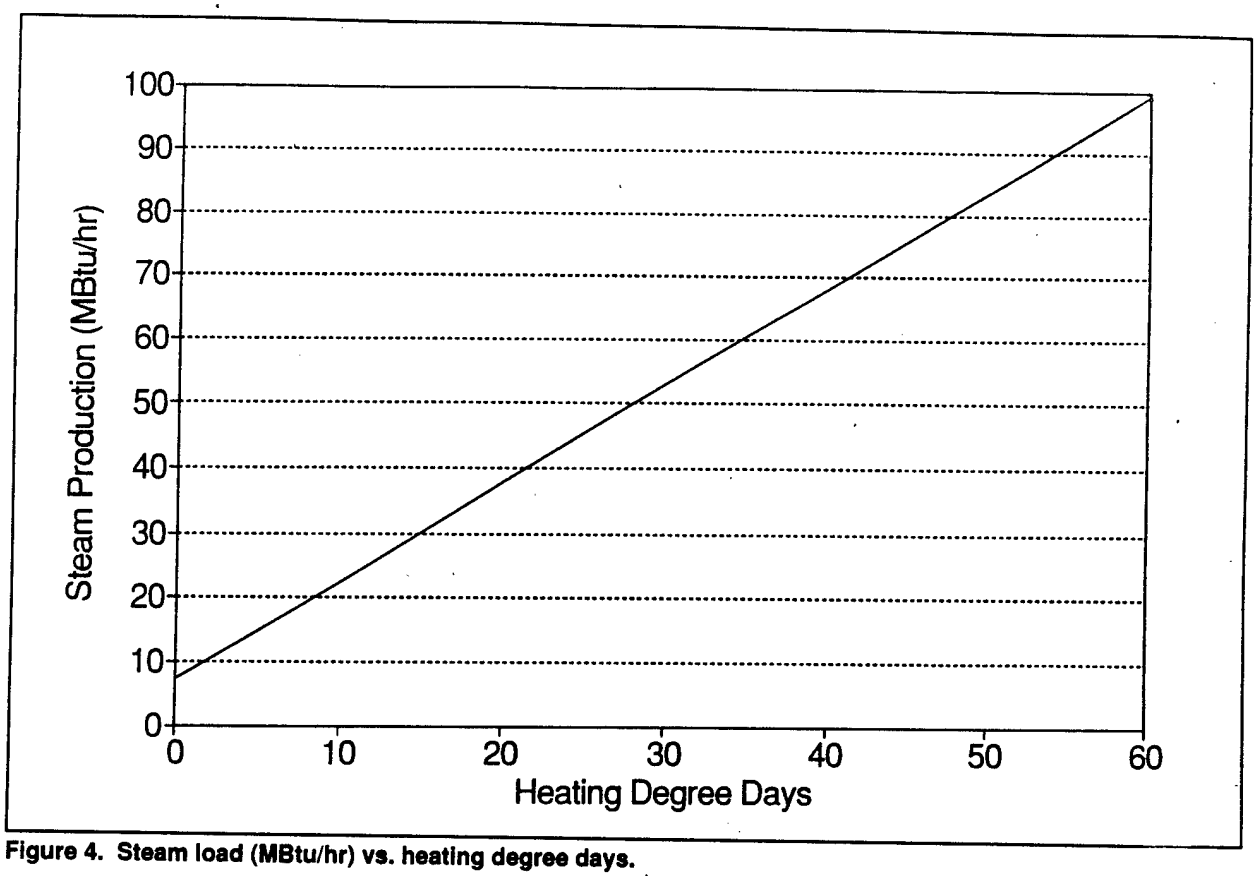

Figure 4. Steam load (MBtu/hr) vs. heating degree days.

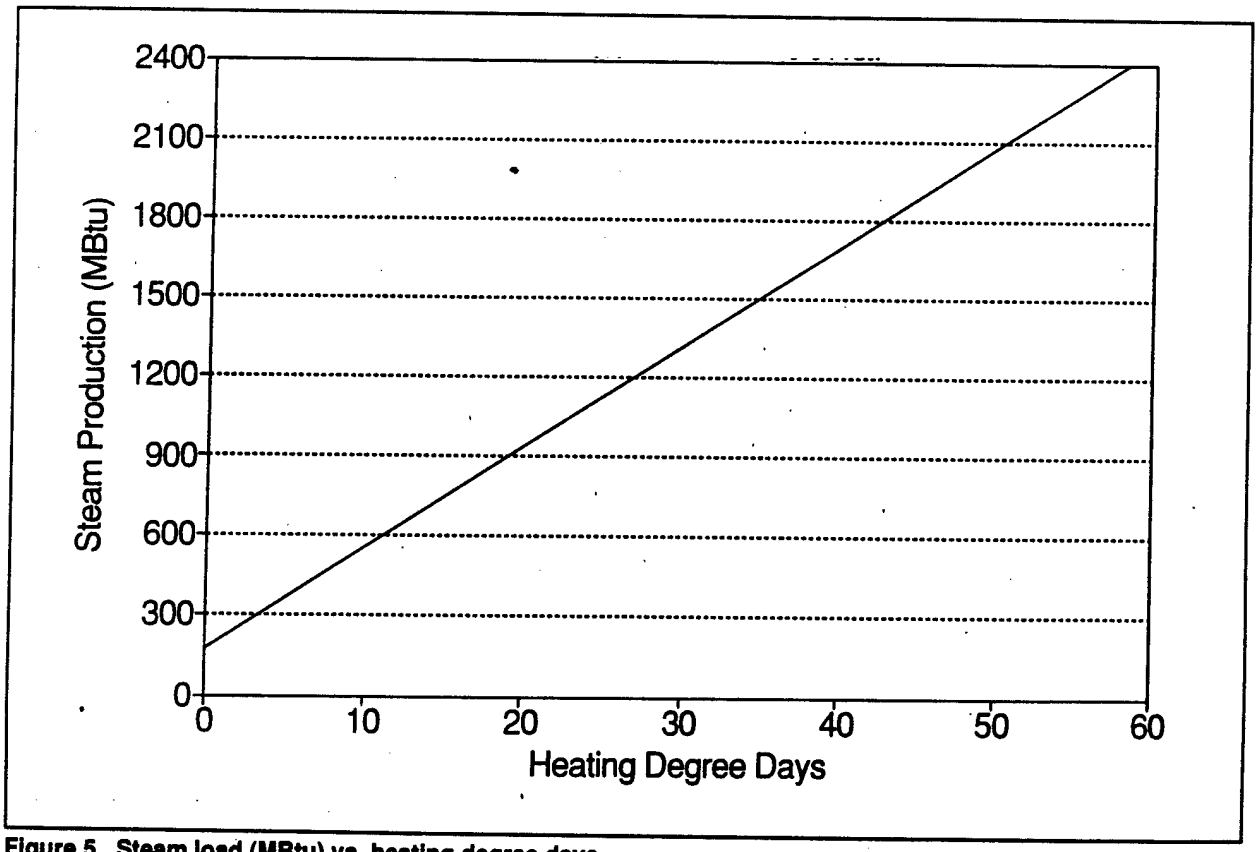

Figure 5. Steam load (MBtu) vs. heating degree days.

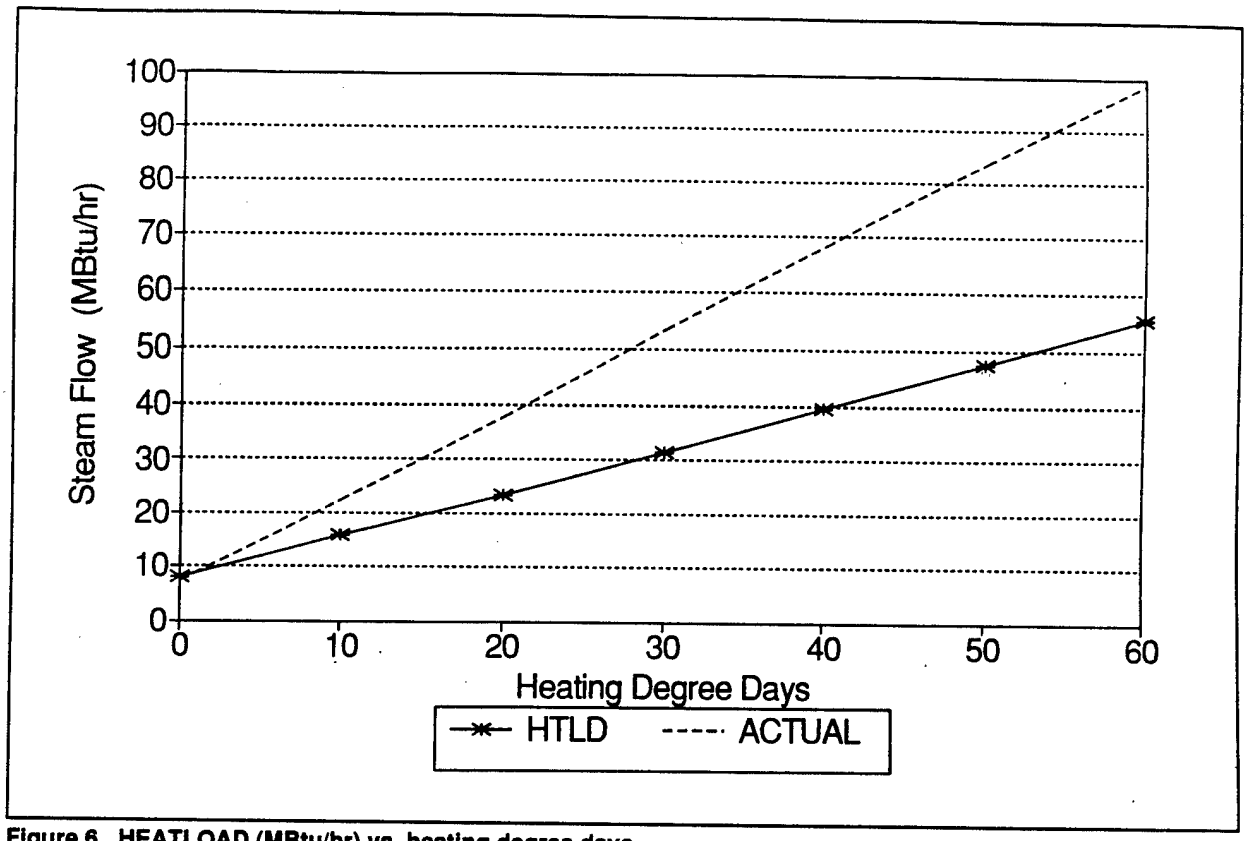

Figure 6. HEATLOAD (MBtu/hr) vs. heating degree days.

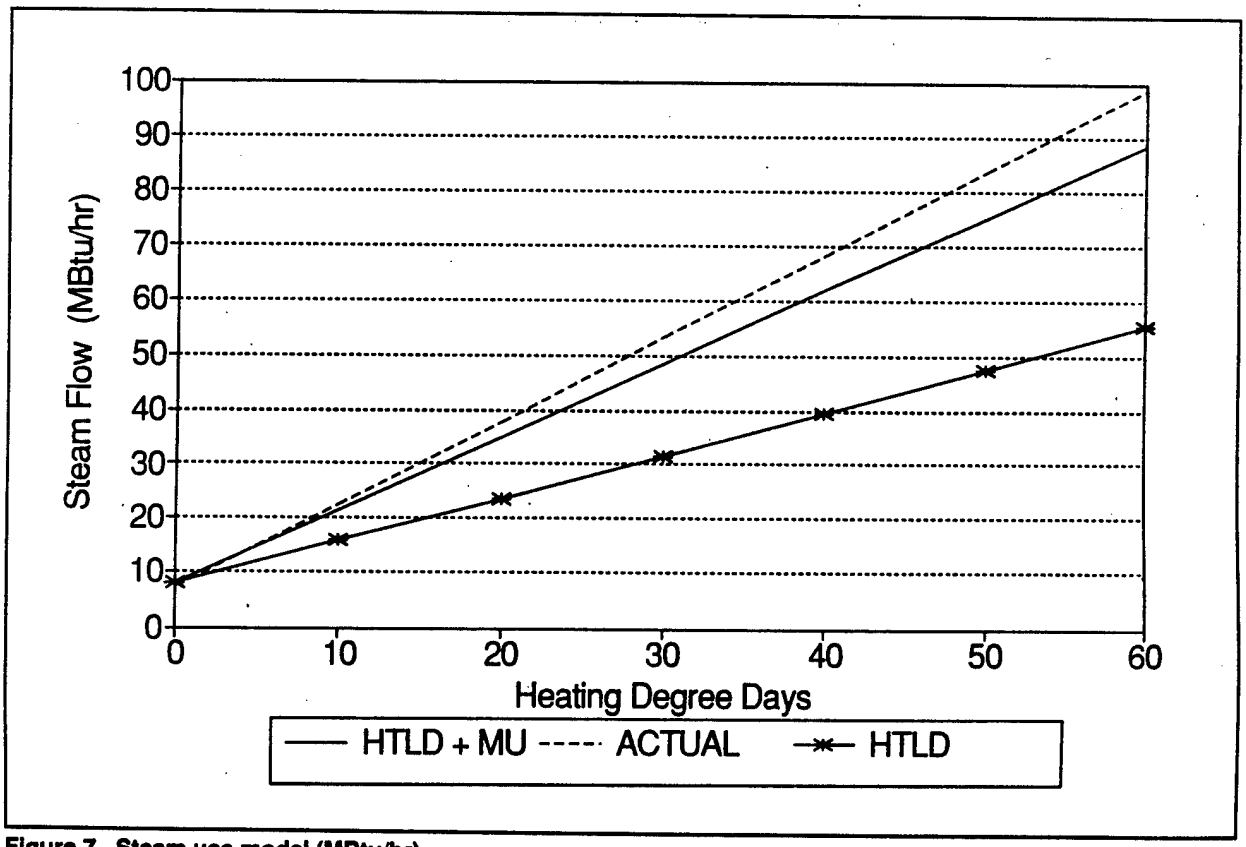

Figure 7. Steam use model (MBtu/hr).

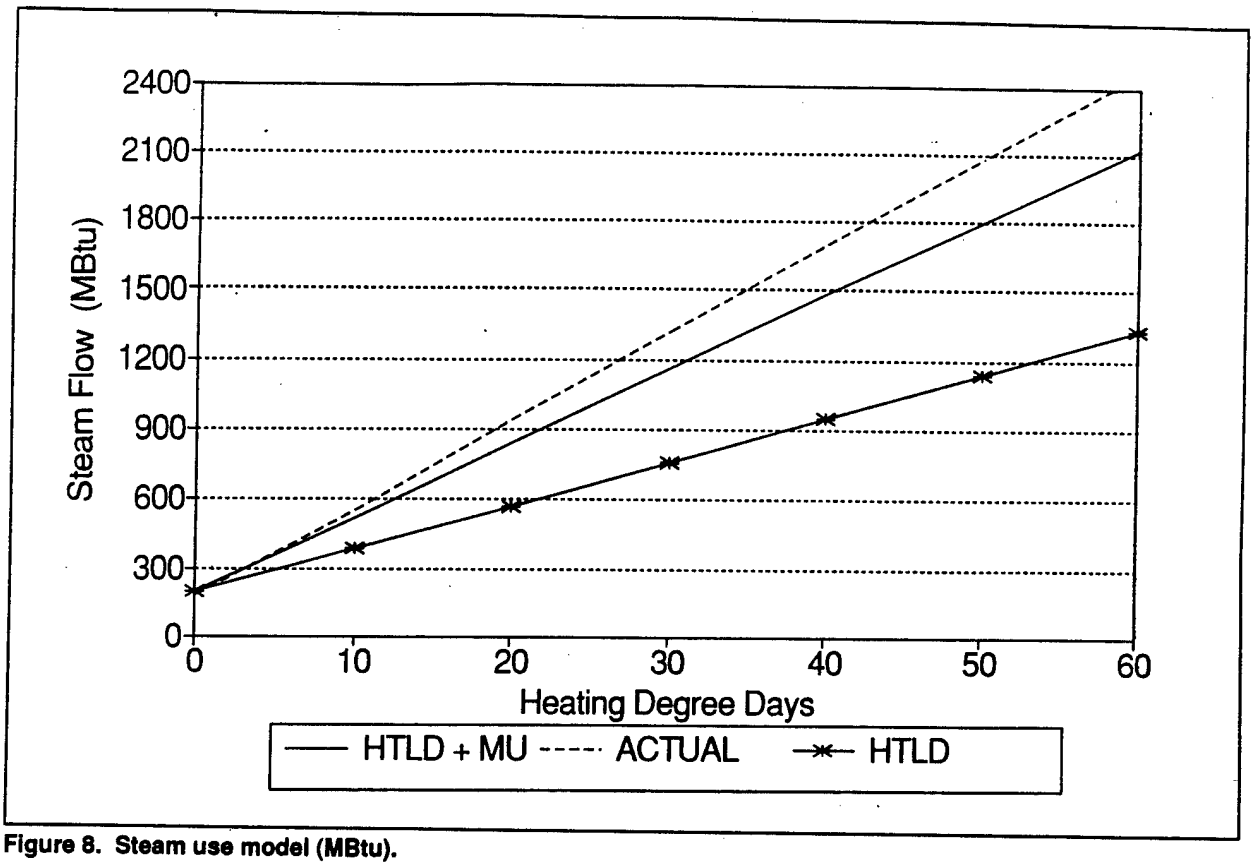

Figure 8. Steam use model (MBtu).

4 Electrical Power Consumption

Niagara Mohawk Power Corporation supplies electric power to WVA. Table 7 shows the rate schedule. The average cost of electricity reported by WVA was $0.078 per kilowatt-hour (kWh), which equals $22.93 per million Btu. Electricity use at WVA is heavily influenced by the use of process energy for manufacturing, and remains essentially constant throughout the typical year. Table 8 includes the monthly and annual electricity costs for WVA during 1992 and 1993. Figure 9 shows unscheduled process electric demand for a day in 1990 for the large manufacturing systems at the facility. Figure 10 shows the on-peak demand profile in kilowatts (kW) for 1993. The peak demand approaches 10,000 kW and the minimum load over the course of the year is approximately 8,000 kW. Figure 11 shows the electricity consumption in kWh for WVA in 1993. Monthly electricity use usually falls between 3,600,000 kWh and 4,100,000 kWh due to the high process electricity requirements of the manufacturing equipment at WVA. Electricity consumption (kWh) is plotted against cooling degree days (CDD) in Figure 12. On-Peak demand (kW) is plotted against CDD in Figure 13.

Table 7. Electric rate schedule.

Customer charge:	$769.72 per month
On-peak energy charge:	$0.066/kWh, $19.34/MBtu (0800-2200 hrs., Mon-Fri)
Off-peak energy charge:	$0.055/kWh, $16.11/MBtu
Demand charge:	$6.985/kW/month
Power factor charge:	$1.0864/RKVA lagging reactive demand (KVAR)
Source:	Niagara Mohawk Electric Bill, October 1993
Average cost:	$0.0782/kWh, $22.93/MBtu

Table 8. Total WVA electricity expenditures, 1992 and 1993.

Month	Total Electricity Cost, 1993	Total Electricity Cost, 1992
January	307,972	239,830
February	332,136	299,807
March	305,481	282,154
April	296,874	287,479
May	276,042	315,042
June	304,326	318,738
July	315,560	318,738
August	293,650	347,012
September	293,650	380,981
October	264,867	342,811
November	291,090	319,442
December	291,090	310,753
Total	**3,711,237**	**3,680,879**

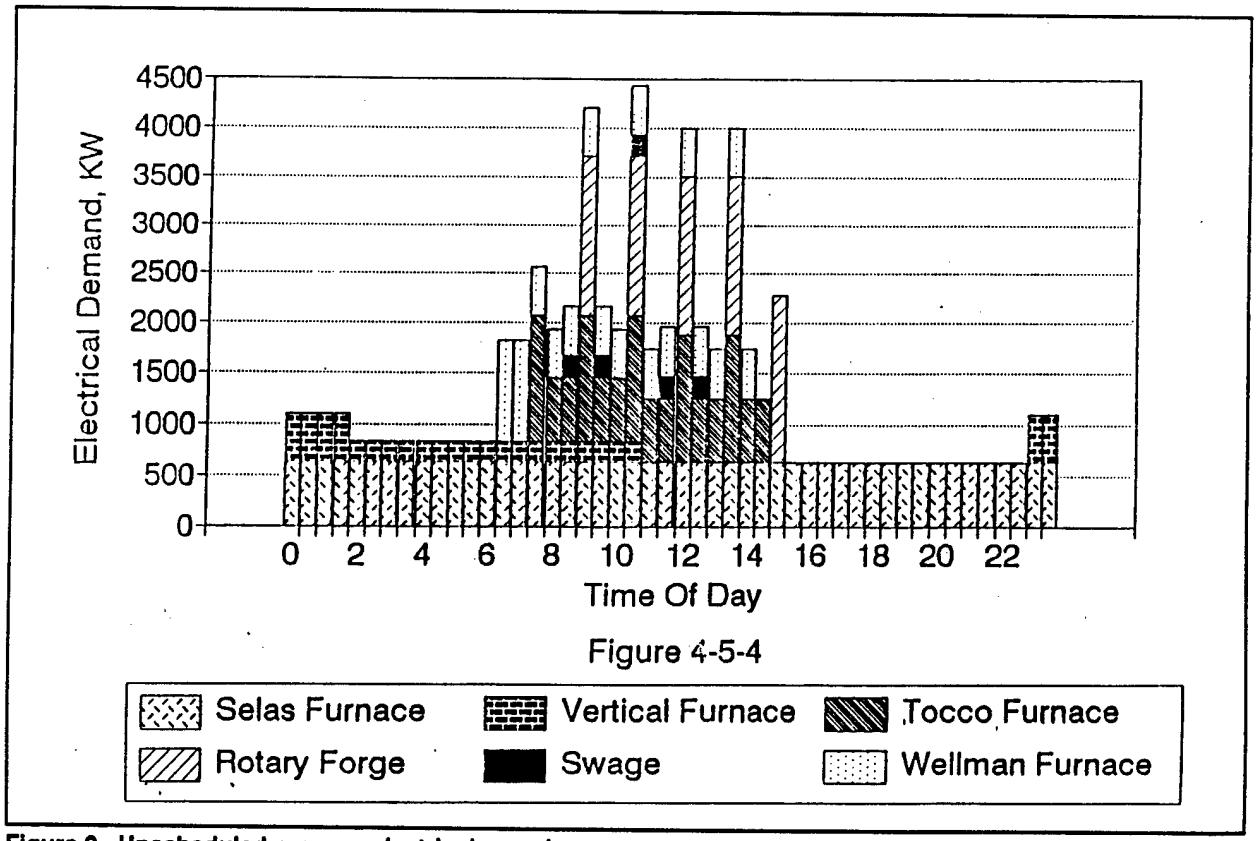

Figure 9. Unscheduled process electric demand.

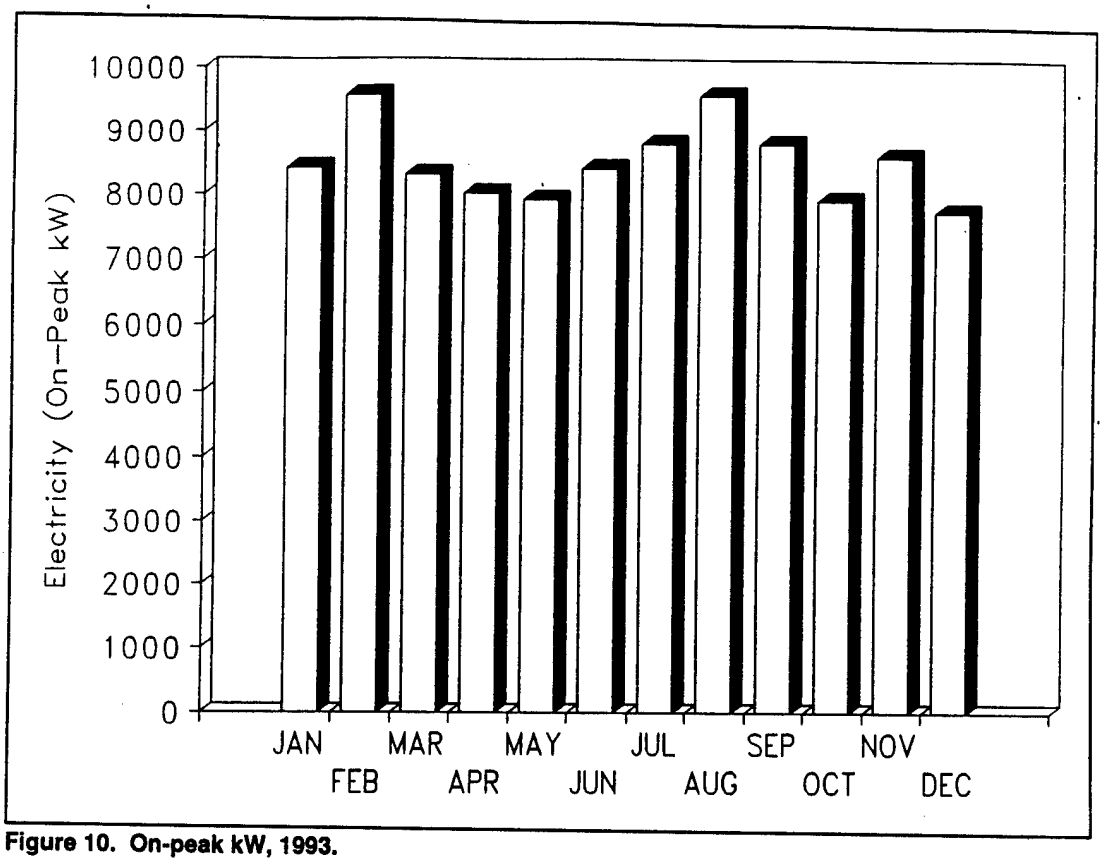

Figure 10. On-peak kW, 1993.

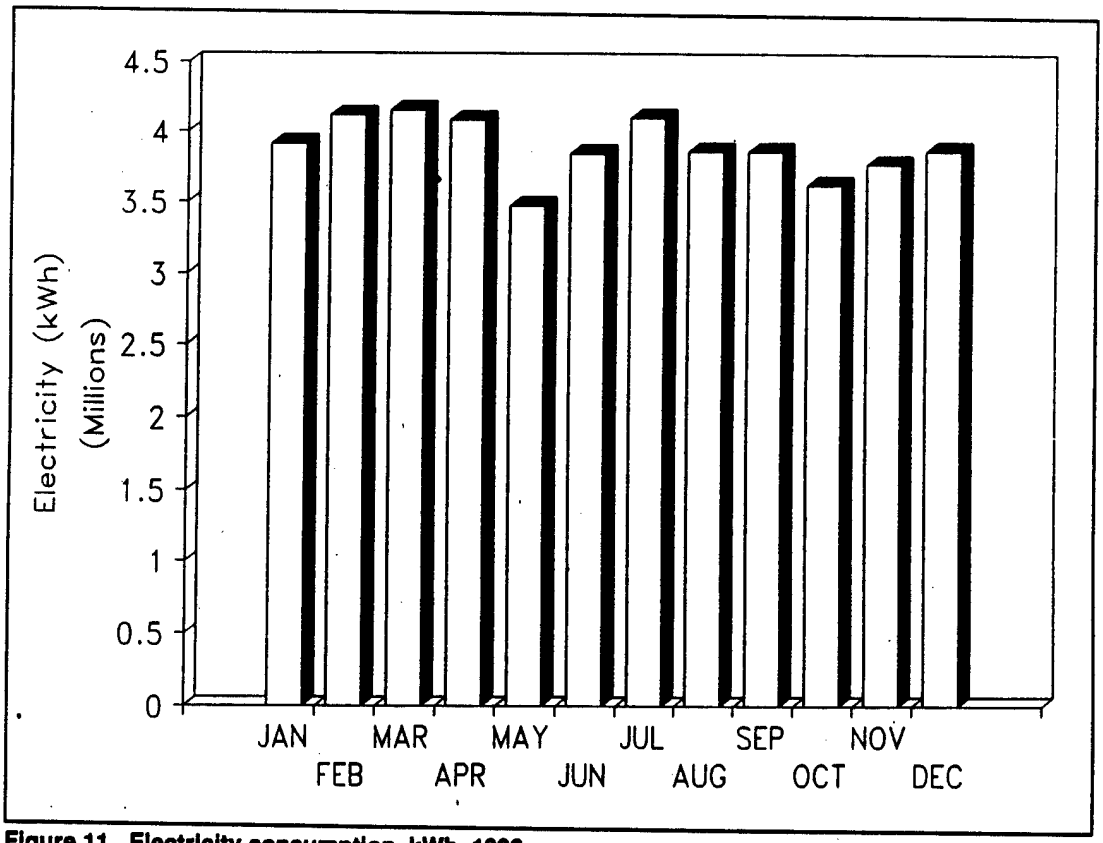

Figure 11. Electricity consumption, kWh, 1993.

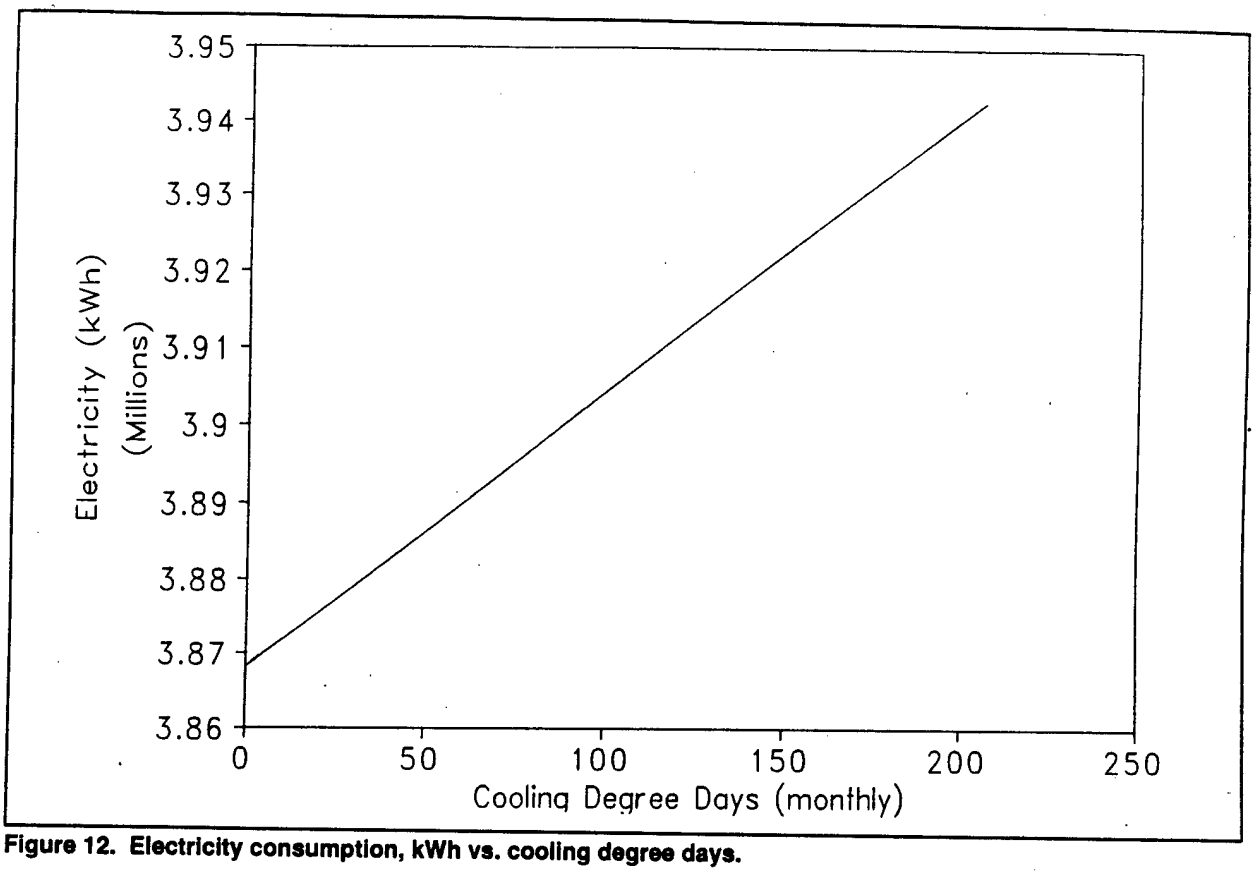

Figure 12. Electricity consumption, kWh vs. cooling degree days.

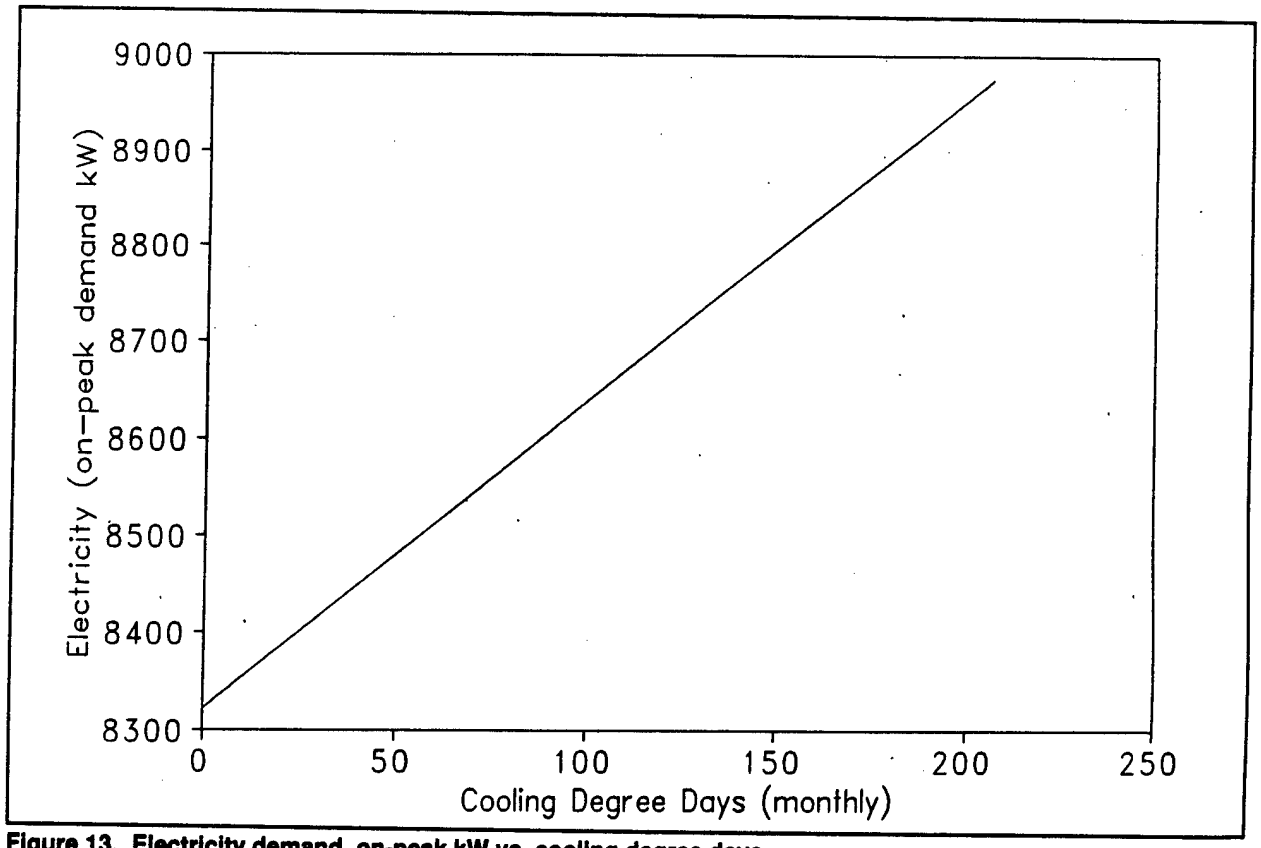

Figure 13. Electricity demand, on-peak kW vs. cooling degree days.

5 Projected Energy Consumption

WVA is not planning any large scale increase or decrease in the number of facility buildings that would significantly impact the CHP or electrical power use. The existing plant average daily production for January and February 1993 was 61,435 lb/hr. The maximum daily average steam production during the first 2 months of 1993 was 74,454 lb/hr, occurring on 1 February 1993. The recommended plant firm peak design capacity was set at 95,000 lb/hr to allow the CHP to meet the expected load at WVA. The plant firm capacity is the plant output with the largest boiler out of service. The plant could then meet the load if the largest boiler were down for maintenance or had some component failure that forced it off line. Figure 4, Steam Load (MBtu/hr) vs. HDD, and Figure 5, Steam Load (MBtu) vs. HDD, serve as the steam production model.

The consumption in the normal year was developed by taking electricity use data from 1992, a year similar to the average weather year in terms of cooling degree days, and adjusting it to match the average cooling degree day year. The consumption for a normal year peaks slightly higher than the 1993 year, but is not higher in all months. Table 9 gives a tabulation of the 1993 electrical use and the predicted usage for a normal (average) year. The data and predictions in Table 9 show that the electrical consumption at WVA is essentially independent of cooling load. The electrical consumption at WVA is primarily determined by the electricity-intensive manufacturing processes. The electricity use at WVA is fairly consistent and heavily dependent on manufacturing process. The electricity consumption model was fairly represented by the data given in Figures 10 and 11 and Table 9.

Table 9. Electrical loads, normal and 1993.

Month	Normal CDD	Estimated Normal Electrical Load (kWh)	1993 CDD	1993 Electrical Load - kWh
January	0	3,868,213	0	3,916,504
February	0	3,868,213	0	4,120,578
March	0	3,868,213	0	4,151,058
April	2	3,868,936	2	4,077,133
May	15	3,873,632	15	3,473,564
June	62	3,890,612	122	3,844,456
July	206	3,942,634	258	4,097,972
August	143	3,919,874	221	3,860,479
September	8	3,871,103	55	3,860,479
October	0	3,868,213	2	3,619,640
November	0	3,868,213	0	3,773,777
December	0	3,868,213	0	3,866,766

6 Study Alternatives

Status Quo Alternative

The status quo (baseline) alternative was developed using the STATUS QUO computer program. STATUS QUO was developed by USACERL for the DOD Coal Use Program to provide a microcomputer-based technique to establish the existing condition of a CHP. The "status quo" situation implies the continued operation of the plant by performing routine maintenance and repair along with replacement of the various pieces of equipment on a scheduled basis. The STATUS QUO model provides a baseline alternative with which to compare the other plant alternatives.

The evaluation of the status quo of the CHP is determined through a field survey of the plant equipment. Evaluation forms are completed for all major components in the plant. The model is capable of estimating the life expectancy and cost of boiler equipment in the 20 to 200 million Btu/hr range. The model input consists of equipment size, capacity, performance data, general condition, and year of installation. The STATUS QUO program will display the year the equipment should be replaced and the equipment cost in the study year dollars. Costs are based on average industry prices and the replacement year is based on industry experience and average expected equipment life.

The program allows the default values to be changed if better information is available. For instance, a good method for establishing water-tube boiler life is to measure the steam drum metal thickness and compare it to the original thickness and pressure rating. Boiler codes limit allowable pressures, which are based on the drum metal thickness. Other components have methods available to determine the condition of the component and its life expectancy. Vibration analysis, motor testing, ultrasonic testing, thickness testing, oil analysis, infrared thermal surveys, eddy current testing, equipment performance tracking, and equipment run time can all be used as an indication of the current condition of equipment and can help predict a remaining useful life.

The program contains default values for labor, maintenance, spare parts, and utility costs. The actual plant operating costs should be used if they are available. The STATUS QUO model uses the LCCID program to perform the LCC analysis, and

produces an LCCID input file containing all the plant components with their replacement cost, year the equipment will be replaced, along with labor, maintenance, spare parts, and utility costs.

For the Status Quo case, the two existing 110,000 lb/hr boilers (Boilers 3 and 4) would be replaced in the year 2001, and Boilers 1 and 2 would not be operated (essentially abandoned in place). Replacement burners would be included with the new boilers in 2001.

Table 10 shows the LCC summary for this alternative. Costs shown are the 1994 net present worth of the LCC of the plant based on a 25-year life. The cost for the No. 2 oil is based on the reported cost of $0.78 per gal or $5.62 per million Btu.

The maintenance labor and supply costs are estimated from the cost predictions from the CHPECON (Central Heating Plant Economics) Program and plant information. The discount rate used in the LCC analyses is 4.0 percent. The escalation rate is 0.84 percent for electricity and 2.50 percent for No. 2 oil. Appendix A includes a copy of the computer program output.

Alternative 1: New Gas/Oil Boilers

Alternative 1 replaces the existing boilers (#3 and #4) with new gas/oil boilers in 1996. The two 110,000 lb/hr boilers would be replaced by two 110,000 lb/hr natural gas boilers. The plant operating pressure would remain at 135 psig. The new boilers would allow the plant to meet the peak load with one large boiler out of service and would allow the plant to turn down to the steaming rates that it can now achieve more efficiently.

Table 10. Status quo alternative LCC summary.

Initial Investment Cost		$0
Energy Costs: Electricity Fuel Oil	 $1,082,748 $39,990,180	
Total Energy Cost		$41,072,928
Recurring Maintenance, Repair, and Custodial Costs		$16,938,960
Major Repair and Replacement Costs		$3,827,140
Base Electricity Cost		$76,500,000
Net Present Worth of the LCCs and Benefits (1994 $)		$138,339,028

The boiler burners would be set up to fire natural gas or No. 2 fuel oil. The fuel oil would be a standby fuel used only if the gas supply were interrupted. The new burners would be low NO_x burners. Economizers would be provided for the new 110,000 lb/hr boilers. Boiler efficiency would be 82 percent when firing natural gas and 85 percent when firing fuel oil. New controls would be furnished with the new boilers. The existing fuel oil system would be used to handle the No. 2 fuel oil. One of the new 110,000 lb/hr boilers could be installed in the same location as Boiler 1 or Boiler 2 and the space left by removal of the other boiler would be vacant, allowing for the possible future addition of cogeneration, gas cooling, or fuel cell equipment. The second new boiler would replace Boiler 4. Boiler 3 could be left in place and used until the new boilers were completed and then kept as a reserve unit or removed to accommodate other equipment.

Table 11 shows the LCC summary for this alternative. Costs shown are the 1994 net present worth of the LCC of the plant, based on a 25-year life. Appendix A includes a copy of the cost estimate. The fuel cost for operation of the new boilers is lower than the fuel cost for the Status Quo alternative because of the increased efficiency (conservatively set for 5 percent savings) of the new boilers. The annual maintenance labor and service cost estimates are the same for the New Gas/Oil Boiler alternative and the Status Quo alternative.

Alternative 2: New Natural Gas-Fired Plant

The new plant includes three 36,000 lb/hr steam boilers. The number and size of boilers was calculated by the CHPECON program based on average monthly steam flow data from WVA. The boilers would be fitted with gas/oil burners. Boiler efficiency would be 80.8 percent when firing natural gas. Number 2 oil would be

Table 11. New gas/oil boilers (installed in 1996) alternative LCC summary.

Initial Investment Cost		$0
Energy Costs:		
Electricity	$1,031,009	
Fuel Oil	$36,279,440	
Total Energy Cost		$37,310,449
Recurring Maintenance, Repair, and Custodial Costs		
Major Repair and Replacement Costs		$4,403,923
Base Electricity Cost		$76,500,000
Net Present Worth of the LCCs and Benefits (1994)		$135,153,332

used as the reserve fuel during natural gas supply interruptions. Table 12 shows the LCC summary for this alternative. Costs shown are the 1995 net present worth of the LCC of the plant based on a 25-year life. The investment cost listed is the cost of building the new facility. Appendix B includes a copy of the CHPECON results.

Alternative 3: New No. 2 Oil-Fired Plant

As in the previous option, the new plant includes three, 36,000 lb/hr steam boilers. The number and size of boilers was calculated by the CHPECON program based on average monthly steam flow data from WVA. Heating plant efficiency would be 84.1 percent when firing No. 2 oil. Table 12 shows the LCC summary for this alternative. Costs shown are the 1995 net present worth of the LCC of the plant based on a 25-year life. The investment cost listed is the cost of building the new facility. Appendix B includes a copy of the CHPECON results. The Operation and Maintenance (O&M) costs are identical to those predicted for the New Natural Gas-Fired Plant (Alternative 2). The energy cost is slightly higher that that of Alternative 2 because of higher fuel cost.

Alternative 4: New Natural Gas-Fired Plant With Cogeneration

The new cogeneration plant includes three 42,000 lb/hr steam boilers with a cogeneration system sized for the plant maximum continuous rating of 125,000 lb/hr. The number and size of boilers was calculated by the CHPECON program based on average monthly steam flow data from WVA. The boilers would be fitted with gas/oil burners. Boiler efficiency would be 80.9 percent when firing natural gas. No. 2 oil would be used as the reserve fuel. Table 12 shows the LCC summary for the cogen-

Table 12. New plant options LCC summary.

	New Plant Natural Gas	New Plant #2 Oil	Cogeneration Follow Heat Load	Cogeneration Operate All Year
Investment	$5,552,055	$5,552,055	$12,679,887	$13,479,820
Plant Energy Cost	$42,911,903	$43,074,246	$49,927,858	$99,080,786
Annual O&M	$8,280,674	$8,280,674	$9,005,485	$12,735,865
Non-Annual O&M	$250,552	$250,552	$1,117,963	$1,133,706
Base Electricity Cost	$76,500,000	$76,500,000	$76,500,000	$76,500,000
Electricity Credit			$38,725,304	$77,213,909
Total LCC ('94)	**$133,495,184**	**$133,657,527**	**$110,505,889**	**$125,716,268**

eration alternative with natural gas as the primary fuel. The first cogeneration option presented in Table 12 is for operation following the heat load and the second cogeneration option shown is for operating the cogeneration system all year. Costs shown are the 1995 net present worth of the LCC of the plant, based on a 25-year life. Appendix B includes a copy of the CHPECON results.

7 Conclusions

The thermal and electrical energy usage at Watervliet Arsenal, NY was studied as part of an investigation of modernization alternatives for the Central Heating Plant. The energy consumption data was used to create thermal and electrical energy models. Thermal energy supply options were evaluated and compared to continued operation of the existing CHP on a life cycle cost basis. The baseline (status quo) option was developed for comparison of the alternatives to the existing situation. LCC analyses were performed to determine the option with the lowest LCC.

Based on the available data, *Alternative 4: New Natural Gas Fired Plant With Cogeneration*, has the lowest LCC based on a 25-year facility life. This option includes replacing Boilers 3 and 4 with new steam boilers and implements a cogeneration system operated during the heating season, when the CHP normally operates. A potential drawback to Alternative 4 is the relatively high initial investment cost, though this option does produce substantial financial savings in the long term through the process of cogeneration. Although *Alternative 1: New Gas/Oil Boilers* (in the existing facility) has a larger LCC than Alternative 4, it has lower initial investment costs (included in the status quo program as Major Repair/ Replacement costs in 1996), which are attractive in the short term. If Alternative 1 were chosen, the cogeneration system could be added sometime in the future, placed in the current location of Boilers 1 and 2.

It is recommended that, when the low NOx boiler demonstration project is completed, which will replace Boiler 4, WVA should continue using the new boiler and replace or refurbish Boiler 3 (pursuant to *Alternative 1: New Gas/Oil Boilers*). These two boilers would provide enough steam capacity to drive a cogeneration system (as identified in Alternative 4). A boiler useful life inspection could be performed on Boiler 3 to determine its actual remaining life before deciding to refurbish or replace it. Any plans for its replacement should be made in conjunction with the investigation of a cogeneration alternative, and should provide the necessary connections to facilitate future connection to a cogeneration system. Boiler 5 should also be maintained to provide an additional increment of steam capacity if either Boiler 3 or 4 becomes inoperable during the heating season.

Appendix A: LCC Analyses

LIFE CYCLE COST ANALYSIS STUDY: WVAR
LCCID 1.065 DATE/TIME: 02-08-95 10:56:29
PROJECT NO., FY, & TITLE: FY 1995 STATUS QUO
INSTALLATION & LOCATION: WATERVLIET ARSENAL NEW YORK
DESIGN FEATURE:
ALT. ID. A; TITLE: STATUS QUO
NAME OF DESIGNER:

BASIC INPUT DATA SUMMARY

CRITERIA REFERENCE:Tri-Service MOA for Econ Anal/LCC (Energy)

DISCOUNT RATE: 4.0%

KEY PROJECT-CALENDAR INFORMATION

DATE OF STUDY (DOS)	JAN 94
MIDPOINT OF CONSTRUCTION (MPC)	JAN 95
BENEFICIAL OCCUPANCY DATE (BOD)	JAN 96
ANALYSIS END DATE (AED)	JAN 21

COST / BENEFIT DESCRIPTION	COST IN DOS $ ($ X 10**0)	EQUIVALENT UNIFORM DIFFERENTIAL ESCALATION RATE (% PER YEAR)	TIME(S) COST INCURRED
INVESTMENT COSTS	.0	.00	JAN 95
ELECTRICITY	65740.3	.84	JUL96-JUL20
ELECT DEMAND	.0	.00	JUL96-JUL20
DISTILLATE OIL	1938782.0	2.50	JUL96-JUL20
MAINT LABOR	540000.0	.00	JUL96-JUL20
MAINT SERV	610000.0	.00	JUL96-JUL20
OPACMONITOR	50000.0	.00	JAN 01
STACK	50000.0	.00	JAN 01
AIRHEAT	58500.0	.00	JAN 01
AIRPHEAT	8750.0	.00	JAN 01
DRUMCTL	5000.0	.00	JAN 01
DRUMCTL	5000.0	.00	JAN 07
DRUMCTL	5000.0	.00	JAN 08
FTBOILER	600000.0	.00	JAN 03
FTBURNER	42752.0	.00	JAN 03
FW_REG	600.0	.00	JAN 01
FW_REG	2400.0	.00	JAN 18
RELVALVE	2344.0	.00	JAN 98
RELVALVE	1953.0	.00	JAN 01
RELVALVE	1969.0	.00	JAN 01
RELVALVE	5859.0	.00	JAN 01
RELVALVE	5907.0	.00	JAN 01
WTBOILER	3200000.0	.00	JAN 01
WTBURNER	200000.0	.00	JAN 01
WTBURNER	103333.0	.00	JAN 01
PUMPSIMPLEX	6000.0	.00	JAN 11
TANKPOLY	800.0	.00	JAN 11
BOILMASTER	5000.0	.00	JAN 01
BOILMASTER	5000.0	.00	JAN 17
DAMPACT	1100.0	.00	JAN 01
DAMPACT	1100.0	.00	JAN 17

LCCID 1.065 DATE/TIME: 02-08-95 10:56:29
PROJECT NO., FY, & TITLE: FY 1995 STATUS QUO
INSTALLATION & LOCATION: WATERVLIET ARSENAL NEW YORK
DESIGN FEATURE:
ALT. ID. A; TITLE: STATUS QUO
NAME OF DESIGNER:

BASIC INPUT DATA SUMMARY

FLAMESAFE	20000.0	.00	JAN 01
FLAMESAFE	20000.0	.00	JAN 17
O2TRIM	10000.0	.00	JAN 17
OILREMOVAL	80000.0	.00	JAN 01
CONDPUMP	18750.0	.00	JAN 98
CONDREC	15600.0	.00	JAN 01
DAIRHEATER	67500.0	.00	JAN 01
FEEDPUMP	40000.0	.00	JAN 15
FWHEATER	55800.0	.00	JAN 01
NAGPIPEBELOW	6000.0	.00	JAN 19
PUMP	8000.0	.00	JAN 17
TANKABOVE	187000.0	.00	JAN 05
FLASHTANK	1550.0	.00	JAN 01
SZSOFT	256800.0	.00	JAN 01
LIGHTS	20.0	.00	JAN 18
ROOF	7.0	.00	JAN 14

OTHER KEY INPUT DATA

LOCATION - NEW YORK CENSUS REGION: 1
RATES FOR INDUSTRIAL SECTOR. TABLES FROM OCT 92

ENERGY USAGE:	10**6 BTUS		ELECTRIC DEMAND:	10**0 DOLLARS
ENERGY TYPE	$/MBTU	AMOUNT	ELECT. DEMAND	PROJECTED DATES
ELECT	22.93	2867.0	.0	JAN96-JAN21
DIST	5.62	344979.0		JAN96-JAN21

LCCID 1.065 DATE/TIME: 02-08-95 10:56:29
PROJECT NO., FY, & TITLE: FY 1995 STATUS QUO
INSTALLATION & LOCATION: WATERVLIET ARSENAL NEW YORK
DESIGN FEATURE:
ALT. ID. A; TITLE: STATUS QUO
NAME OF DESIGNER:

LIFE CYCLE COST TOTALS*

INITIAL INVESTMENT COSTS		0.
ENERGY COSTS:		
ELECTRICITY	1082748.	
DISTILLATE OIL	39990180.	
TOTAL ENERGY COSTS		41072930.
RECURRING M&R/CUSTODIAL COSTS		16938960.
MAJOR REPAIR/REPLACEMENT COSTS		3827140.
OTHER O&M COSTS & MONETARY BENEFITS		0.
DISPOSAL COSTS/RETENTION VALUE		0.
LCC OF ALL COSTS/BENEFITS (NET PW)		61839030.

*NET PW EQUIVALENTS ON JAN94; IN 10**0 DOLLARS; IN CONSTANT JAN94 DOLLARS
*ENERGY ESCALATION RATES FROM NIST HANDBOOK 135 SUPPLEMENT DATED OCT 92

LCCID 1.065 DATE/TIME: 02-08-95 10:56:29
PROJECT NO., FY, & TITLE: FY 1995 STATUS QUO
INSTALLATION & LOCATION: WATERVLIET ARSENAL NEW YORK
DESIGN FEATURE:
ALT. ID. A; TITLE: STATUS QUO
NAME OF DESIGNER:

YEAR-BY-YEAR BREAKDOWN OF LIFE CYCLE COSTS*

DOLLARS IN 10**0

BENEFICIAL OCCUPANCY DATE: JAN96
ANNUAL PAYMENTS OCCUR: JUL96 THROUGH JUL20

PAY	ELECT	DIST	M & R	R / R	OTHER
1	60517.	1884006.	1042592.	0.	0.
2	58570.	1880251.	1002493.	0.	0.
3	56879.	1875664.	963935.	18031.	0.
4	55291.	1873248.	926861.	0.	0.
5	54053.	1869782.	891212.	0.	0.
6	52878.	1855276.	856935.	3188023.	0.
7	51242.	1832184.	823976.	0.	0.
8	49593.	1802828.	792284.	451589.	0.
9	48108.	1767913.	761812.	0.	0.
10	46813.	1731770.	732512.	121472.	0.
11	45430.	1692273.	704338.	0.	0.
12	44090.	1652104.	677248.	3003.	0.
13	42515.	1614158.	651200.	2887.	0.
14	41007.	1575646.	626154.	0.	0.
15	39986.	1532679.	602071.	0.	0.
16	38791.	1497481.	578915.	3491.	0.
17	37528.	1465408.	556649.	0.	0.
18	36307.	1433593.	535239.	0.	0.
19	35127.	1402053.	514653.	3.	0.
20	33986.	1370817.	494859.	17553.	0.
21	32883.	1339910.	475826.	0.	0.
22	31817.	1309352.	457525.	17893.	0.
23	30776.	1276652.	439927.	944.	0.
24	29768.	1243714.	423007.	2251.	0.
25	28794.	1211421.	406738.	0.	0.
***	1082748.	********	********	3827140.	0.

*NET PW EQUIVALENTS ON JAN94; IN 10**0 DOLLARS; IN CONSTANT JAN94 DOLLARS
*ENERGY ESCALATION RATES FROM NIST HANDBOOK 135 SUPPLEMENT DATED OCT 92

LIFE CYCLE COST ANALYSIS STUDY: WVAR
LCCID 1.065 DATE/TIME: 02-08-95 10:40:55
PROJECT NO., FY, & TITLE: FY 1995 NEW BOILERS IN 1996
INSTALLATION & LOCATION: WATERVLIET ARSENAL NEW YORK
DESIGN FEATURE:
ALT. ID. A; TITLE: STATUS QUO
NAME OF DESIGNER:

BASIC INPUT DATA SUMMARY

CRITERIA REFERENCE:Tri-Service MOA for Econ Anal/LCC (Energy)

DISCOUNT RATE: 4.0%

KEY PROJECT-CALENDAR INFORMATION

DATE OF STUDY (DOS)	JAN 94
MIDPOINT OF CONSTRUCTION (MPC)	JAN 95
BENEFICIAL OCCUPANCY DATE (BOD)	JAN 96
ANALYSIS END DATE (AED)	JAN 21

COST / BENEFIT DESCRIPTION	COST IN DOS $ ($ X 10**0)	EQUIVALENT UNIFORM DIFFERENTIAL ESCALATION RATE (% PER YEAR)	TIME(S) COST INCURRED
INVESTMENT COSTS	.0	.00	JAN 95
ELECTRICITY	62598.9	.84	JUL96-JUL20
ELECT DEMAND	.0	.00	JUL96-JUL20
NATURAL GAS	1697641.0	2.77	JUL96-JUL20
MAINT LABOR	540000.0	.00	JUL96-JUL20
MAINT SERV	610000.0	.00	JUL96-JUL20
OPACMONITOR	50000.0	.00	JAN 01
STACK	50000.0	.00	JAN 01
AIRHEAT	58500.0	.00	JAN 01
AIRPHEAT	8750.0	.00	JAN 01
DRUMCTL	5000.0	.00	JAN 01
DRUMCTL	5000.0	.00	JAN 07
DRUMCTL	5000.0	.00	JAN 08
FTBOILER	600000.0	.00	JAN 03
FTBURNER	42752.0	.00	JAN 03
FW_REG	600.0	.00	JAN 01
FW_REG	2400.0	.00	JAN 18
RELVALVE	2344.0	.00	JAN 98
RELVALVE	1953.0	.00	JAN 01
RELVALVE	1969.0	.00	JAN 01
RELVALVE	5859.0	.00	JAN 01
RELVALVE	5907.0	.00	JAN 01
WTBOILER	3200000.0	.00	JAN 96
WTBURNER	200000.0	.00	JAN 96
WTBURNER	103333.0	.00	JAN 96
PUMPSIMPLEX	6000.0	.00	JAN 11
TANKPOLY	800.0	.00	JAN 11
BOILMASTER	5000.0	.00	JAN 01
BOILMASTER	5000.0	.00	JAN 17
DAMPACT	1100.0	.00	JAN 01
DAMPACT	1100.0	.00	JAN 17

LCCID 1.065 DATE/TIME: 02-08-95 10:40:55
PROJECT NO., FY, & TITLE: FY 1995 NEW BOILERS IN 1996
INSTALLATION & LOCATION: WATERVLIET ARSENAL NEW YORK
DESIGN FEATURE:
ALT. ID. A; TITLE: STATUS QUO
NAME OF DESIGNER:

BASIC INPUT DATA SUMMARY

FLAMESAFE	20000.0	.00	JAN 01
FLAMESAFE	20000.0	.00	JAN 17
O2TRIM	10000.0	.00	JAN 17
OILREMOVAL	80000.0	.00	JAN 01
CONDPUMP	18750.0	.00	JAN 98
CONDREC	15600.0	.00	JAN 01
DAIRHEATER	67500.0	.00	JAN 01
FEEDPUMP	40000.0	.00	JAN 15
FWHEATER	55800.0	.00	JAN 01
NAGPIPEBELOW	6000.0	.00	JAN 19
PUMP	8000.0	.00	JAN 17
TANKABOVE	187000.0	.00	JAN 05
FLASHTANK	1550.0	.00	JAN 01
SZSOFT	256800.0	.00	JAN 01
LIGHTS	20.0	.00	JAN 18
ROOF	7.0	.00	JAN 14

OTHER KEY INPUT DATA

LOCATION - NEW YORK CENSUS REGION: 1
RATES FOR INDUSTRIAL SECTOR. TABLES FROM OCT 92

ENERGY USAGE:	10**6 BTUS		ELECTRIC DEMAND:	10**0 DOLLARS
ENERGY TYPE	$/MBTU	AMOUNT	ELECT. DEMAND	PROJECTED DATES
ELECT	22.93	2730.0	.0	JAN96-JAN21
NAT G	5.18	327730.0		JAN96-JAN21

LCCID 1.065 DATE/TIME: 02-08-95 10:40:55
PROJECT NO., FY, & TITLE: FY 1995 NEW BOILERS IN 1996
INSTALLATION & LOCATION: WATERVLIET ARSENAL NEW YORK
DESIGN FEATURE:
ALT. ID. A; TITLE: STATUS QUO
NAME OF DESIGNER:

LIFE CYCLE COST TOTALS*

INITIAL INVESTMENT COSTS		0.
ENERGY COSTS:		
ELECTRICITY	1031009.	
NATURAL GAS	36279440.	
TOTAL ENERGY COSTS		37310440.
RECURRING M&R/CUSTODIAL COSTS		16938960.
MAJOR REPAIR/REPLACEMENT COSTS		4403923.
OTHER O&M COSTS & MONETARY BENEFITS		0.
DISPOSAL COSTS/RETENTION VALUE		0.
LCC OF ALL COSTS/BENEFITS (NET PW)		58653320.

*NET PW EQUIVALENTS ON JAN94; IN 10**0 DOLLARS; IN CONSTANT JAN94 DOLLARS
*ENERGY ESCALATION RATES FROM NIST HANDBOOK 135 SUPPLEMENT DATED OCT 92

LCCID 1.065 DATE/TIME: 02-08-95 10:40:55
PROJECT NO., FY, & TITLE: FY 1995 NEW BOILERS IN 1996
INSTALLATION & LOCATION: WATERVLIET ARSENAL NEW YORK
DESIGN FEATURE:
ALT. ID. A; TITLE: STATUS QUO
NAME OF DESIGNER:

YEAR-BY-YEAR BREAKDOWN OF LIFE CYCLE COSTS*

DOLLARS IN 10**0

BENEFICIAL OCCUPANCY DATE: JAN96
ANNUAL PAYMENTS OCCUR: JUL96 THROUGH JUL20

PAY	ELECT	NAT G	M & R	R / R	OTHER
1	57626.	1612021.	1042592.	3239028.	0.
2	55771.	1583730.	1002493.	0.	0.
3	54161.	1564419.	963935.	18031.	0.
4	52649.	1564935.	926861.	0.	0.
5	51470.	1567138.	891212.	0.	0.
6	50351.	1568284.	856935.	525778.	0.
7	48793.	1569873.	823976.	0.	0.
8	47224.	1565659.	792284.	451589.	0.
9	45810.	1556130.	761812.	0.	0.
10	44576.	1546255.	732512.	121472.	0.
11	43259.	1524587.	704338.	0.	0.
12	41983.	1503942.	677248.	3003.	0.
13	40483.	1484348.	651200.	2887.	0.
14	39047.	1478531.	626154.	0.	0.
15	38075.	1474211.	602071.	0.	0.
16	36938.	1449407.	578915.	3491.	0.
17	35735.	1418363.	556649.	0.	0.
18	34572.	1387566.	535239.	0.	0.
19	33448.	1357038.	514653.	3.	0.
20	32362.	1326807.	494859.	17553.	0.
21	31312.	1296892.	475826.	0.	0.
22	30296.	1267319.	457525.	17893.	0.
23	29306.	1235667.	439927.	944.	0.
24	28345.	1203788.	423007.	2251.	0.
25	27418.	1172529.	406738.	0.	0.
***	1031009.	********	********	4403923.	0.

*NET PW EQUIVALENTS ON JAN94; IN 10**0 DOLLARS; IN CONSTANT JAN94 DOLLARS
*ENERGY ESCALATION RATES FROM NIST HANDBOOK 135 SUPPLEMENT DATED OCT 92

Appendix B: CHPECON Cases

```
**********************************************************************************
**    Central Heating Plant Economics Evaluation Program              Page 1    **
**    File: WVAR1          Type: New plant (NP)                       01/05/95  **
**    Desc: WATERVLIET ARSENAL                                                  **
**    Tech: Gas / Oil Fired Boiler                                              **
**********************************************************************************

State     : NY - New York
Location :  42d 43m -  73d 42m
County    :
Emission regulation region
#  0 -  State and federal only

Annual heating degree days:  6725

*************************** Boiler Characteristics ****************************

Type of heating system : Steam

Average Monthly Steam Flows (million Btu/hr)

          Jan      Feb      Mar      Apr      May      Jun
           59       65       56       36        8        4
          Jul      Aug      Sep      Oct      Nov      Dec
            3        4        5       35       49       61

Calculated PMCR: 107 thousand lb/hr steam

Boiler technology: Gas / Oil Fired Boiler

Boiler sizes (thousand lb steam/hr) :
       1:  36    2:  36    3:  36

Natural gas composition - volume basis
    82.90 % Methane        0.00 % Ethylene      14.90 % Ethane
     0.00 % Propane        0.00 % Butane         0.00 % Hydrogen
     2.20 % Nitrogen       0.00 % Oxygen         0.00 % Hydrogen Sulfide (H2S)
     0.00 % Carbon Monoxide (CO)                 0.00 % Carbon Dioxide (CO2)
     1107 Btu/SCF Heating Value

Natural gas composition - weight basis
    73.70 % Carbon     22.94 % Hydrogen             0.00 % Oxygen
     0.00 % Sulfur      0.00 % Carbon Monoxide      3.36 % Inert gases (N2, CO2)
      22695 Btu/lb heating value

Boiler Operating Parameters -- Natural Gas
   Combustion air temp:  70 deg F      30 % relative humidity
   Flue gas temp: 350 deg F          3.00 % oxygen (dry basis)
   40.02 % combustibles
   10.25 % CO2                      86.73 % N2
   0.00481 lb/lb dry air            0.00772 mole/mole dry air
    14.94 % excess air              0.020 % combustibles
```

```
**********************************************************************************
**    Central Heating Plant Economics Evaluation Program            Page 2     **
**    File: WVAR1        Type: New plant (NP)                      01/05/95    **
**    Desc: WATERVLIET ARSENAL                                                 **
**    Tech: Gas / Oil Fired Boiler                                             **
**********************************************************************************

Boiler Performance -- Natural Gas
   Sensible dry gas loss:      5.370 %    Loss H2O vapor in air:       0.044 %
   Fuel H2O heat loss:         0.000 %    H2 comb H2O heat loss:      10.741 %
   Radiation heat loss:        1.972 %    Unaccounted for loss:        1.000 %
   Combustible gas heat loss:  0.064 %
   Boiler efficiency:         80.808 %

Fuel Oil #2 composition - weight basis
    87.40 % Carbon    12.50 % Hydrogen          0.00 % Oxygen
     0.00 % Nitrogen   0.10 % Sulfur            0.00 % Ash
     0.00 % Moisture
      18993 Btu/lb heating value
   0.856 Specific gravity

Boiler Operating Parameters -- Fuel Oil #2
   Combustion air temp:  70 deg F     30 % relative humidity
   Flue gas temp: 350 deg F         2.50 % oxygen (dry basis)
   50.02 % combustibles
   13.69 % CO2                     83.79 % N2
   0.00481 lb/lb dry air           0.00772 mole/mole dry air
    12.65 % excess air             0.020 % combustibles

Boiler Performance -- Fuel Oil #2
   Sensible dry gas loss:      5.775 %    Loss H2O vapor in air:       0.048 %
   Fuel H2O heat loss:         0.000 %    H2 comb H2O heat loss:       6.993 %
   Radiation heat loss:        1.972 %    Unaccounted for loss:        1.000 %
   Combustible gas heat loss:  0.068 %
   Boiler efficiency:         84.144 %

************************** Boiler Performance @ PMCR **************************
Blowdown    :   5 %

Temperature out of stack :   350 deg F
Steam pressure           :  150 psig
Steam temperature        :  367 deg F       enthalpy  : 1195.6 Btu/lb
Condensate return temp   :  150 deg F       enthalpy  :  118.0 Btu/lb
Makeup water temperature :   50 deg F       enthalpy  :   18.0 Btu/lb
Inlet water temperature  :  120 deg F       enthalpy  :   88.1 Btu/lb

********************** Area and Water Requirements @ PMCR **********************

Building size :  7500 sq ft              Condensate Return    :    75 %
Plant area    :  1.17 acres              Boiler house leakage :     2 %
Plant height  :    40 ft                 Water requirements   :   100 gpm (est)
Stack height  :    60 ft                 Railway track length :   125 ft
Sewer dischrg :    25 gpm (est)
```

```
********************************************************************************
**    Coal Fired Boiler Evaluation Program                          Page 3    **
**    File: WVAR1          Type: New plant (NP)                     01/05/95  **
**    Desc: WATERVLIET ARSENAL                                               **
**    Tech: Gas / Oil Fired Boiler                                           **
********************************************************************************

************************ General Site Considerations ************************

Development and Construction

Contractors MAY BE AVAILABLE for CHP construction near the base.
The potential of having to bring in contractors for the
construction of the central heating plant can require additional
funds which are not accounted in the cost model.
  Score:   2

     Total:    20/   50      40%

================================================================================

Fuel Supply and Site Access

Gas purchase contracts:
  Score:   0

Oil supply contracts:
  Score:   0

     Total:     0/    0       0%

================================================================================

Ecology

     Total:     0/    0       0%

================================================================================

Social Considerations

     Total:     0/    0       0%

================================================================================

Facility Services
```

```
**********************************************************************************
**    Central Heating Plant Economics Evaluation Program          Page 4     **
**    File: WVAR1          Type: New plant (NP)                   01/05/95   **
**    Desc: WATERVLIET ARSENAL                                               **
**    Tech: Gas /. Oil Fired Boiler                                          **
**********************************************************************************

Condition of system is fair
Additional costs may be required to install a new distribution system.
These costs are not considered in the detailed evaluation program.
  Score:   3

Steam distribution system routing is medium
It may be difficult to incorporate the existing distribution system
into the new plant.  Additional costs may be required heavily modify
the existing distribution system.  These costs are not considered in
the new plant detailed evaluation section of this program.
  Score:   2

City water available: Yes
  Score:   5

New electrical substation required: No
  Score:   5


     Total:   120/  170      70%

==================================================================================


Waste Handling and Emissions

Local sewer system available: Yes
  Score:   5


     Total:    50/   50     100%

==================================================================================


Military


     Total:     0/    0       0%

==================================================================================
```

```
**********************************************************************************
**    Central Heating Plant Economics Evaluation Program            Page 5     **
**    File: WVAR1        Type: New plant (NP)                       01/05/95   **
**    Desc: WATERVLIET ARSENAL                                                 **
**    Tech: Gas / Oil Fired Boiler                                             **
**********************************************************************************
```

General Questions Summary

	Total	Max	Rating
Development and Construction	20	50	40
Fuel Supply and Site Access	0	0	0
Ecology	0	0	0
Social Considerations	0	0	0
Facility Services	120	170	70
Waste Handling and Emissions	50	50	100
Military	0	0	0

Boiler technology rating: 10

Feasibility score: 10/10 = 100%

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 1
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Base and Plant Information
****

State: NY - New York Base DOE Region: 1
PMCR: 107,000 lb/hr steam Number of boilers: 3

Height of the plant: 40 ft
Building area: 7500 sq ft
Plant area: 1.17 acres

****
Facility Parameters
****

Capital Equipment Escalation Factor: 1.102 (5032.16/1995)
Non-Labor Operation & Maintenance Escalation Factor: 1.092 (935.60/1995)
Operation & Maintenance Labor Escalation Factor: 1.119 (4626.82/1995)
Construction Labor Escalation Factor: 1.024 (271.10/1995)

Annual electricity usage: 794,786 kW-hr

1995 cost for distillate: 0.780 $/gallon
1995 cost for residual: 0.600 $/gallon
1995 cost for natural gas: 5.180 $/million Btu
1995 cost for electricity: 0.078 $/kW-hr

Annual Facility Output: 279,504 thousand lb steam
Annual Natural Gas Usage: 346 10^6 SCF
Heating plant efficiency: 80.8% natural gas
Year of Study: 1995
Years of Operation: 1999 - 2023
Annual #2 Fuel Oil Usage: 2,711 10^3 gal
Heating plant efficiency: 84.1% #2 fuel oil

****
Facility Capital Costs
****

Equipment		Cost	Equipment		Cost
Boiler:	$	1,093,737	Stack:	$	34,709
Building/service:	$	1,143,696	Water trtmnt:	$	188,681
Feedwtr pmps:	$	18,757	Cond xfr pmps:	$	16,385
Cond strg tnk:	$	5,934	Oil (long) storage:	$	201,113
Oil day strg pmp:	$	4,958	Oil heaters:	$	5,454
Oil day strg tanks:	$	16,098	Oil unload pumps:	$	14,544
Oil xfr pmps:	$	4,793	Fire protection:	$	44,075
Cont bldn tnk:	$	845	Intr bldn tnk:	$	845
Compressor:	$	27,196	Car puller:	$	22,037
Rail:	$	11,707	Site preparation:	$	3,223
Site improvements:	$	169,139	Mobile equipment:	$	42,973
Elec substation:	$	60,803	Electrical:	$	131,896

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 2
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Capital Costs, cont
****

Piping:	$	747,411	Instrumentation:	$	276,353
Direct costs:	$	1,485,804			

****
Plant installed cost: $ 6,245,307

****
Facility Annual O & M and Energy Costs
****

Operating staff: 10
Annual Labor Costs: $ 514,498
Annual Year Non-Labor O & M Costs : $ 597,295
1999 Natural gas costs : $ 2,212,754
1999 Auxiliary Energy Costs : $ 63,767
1999 #2 fuel oil costs : $ 2,452,774

****
Periodic Major Maintenance Cost Summary
****

Time Interval	Cost	Time Interval	Cost
3 years	$ 30,000	5 years	$ 6,251
10 years	$ 59,691	15 years	$ 73,127
18 years	$ 6,554	20 years	$ 12,862

****
Facility Life Cycle Cost Summary
****

Analysis using natural gas as primary fuel

+ PV 'Adjusted' Investment Costs	= $	5,552,055
+ PV Energy + Transportation Costs	= $	42,911,903
+ PV Annually Recurring O&M Costs	= $	8,280,674
+ PV Non-Annually Recurring Repair & Replacement	= $	250,552
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	56,995,185

Levelized Cost of Service (1999 start) = 12.772 $/MMBtu
Levelized Cost of Service (1999 start) = 15.270 $/1000 lb steam

****
Facility Life Cycle Cost Summary
****

Analysis using #2 fuel oil as primary fuel
+ PV 'Adjusted' Investment Costs = $ 5,552,055

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 3
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Life Cycle Cost Summary, cont
****

+ PV Energy + Transportation Costs	= $	43,074,246
+ PV Annually Recurring O&M Costs	= $	8,280,674
+ PV Non-Annually Recurring Repair & Replacement	= $	250,552
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	57,157,529

Levelized Cost of Service (1999 start) = 12.808 $/MMBtu
Levelized Cost of Service (1999 start) = 15.313 $/1000 lb steam

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 1
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Base Information
****

State: NY - New York Base DOE Region: 1
PMCR: 107,000 lb/hr steam Number of boilers: 3

Steam Properties: 150 psi (1195.6 Btu/lb)
Inlet water temp: 120 deg F enthalpy: 88.1 Btu/lb

****
Boiler Design Parameters
****

A mixed bed for condensate polishing IS NOT NEEDED
A dealkalizer unit IS INCLUDED

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 2
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Plant Design Parameters --- Space Requirements
****

Height of the plant: 40 ft
Building area: 7500 sq ft
Plant area: 1.17 acres

****
Plant Design Parameters --- Water & Water Treatment Specifications
****

Number of deaerators: 1
Number of resin vessels / train: 1
Number of mixed beds / train: 0
Boiler 1: 1 motor-driven feedwater pump -- 69 gpm
Boiler 2: 1 motor-driven feedwater pump -- 69 gpm
Boiler 3: 1 motor-driven feedwater pump -- 69 gpm
Number of condensate transfer pumps: 3
Condensate transfer pump size: 848 gpm

Condensate storage tank size: 3430 gallons
Number of long term oil storage tanks: 1
Capacity of one long term oil storage tank: 625000 gal
Number of oil (day storage) pumps: 3
Short term storage tank size: 3,464 gallons

Length of rail track: 125 ft
Annual personnel water use: 89,162 gallons

```
Central Heating Plant Economics Evaluation Program -- Cost Analysis      Page 3
File: WVAR1        Type: New plant (NP)                                  01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

*******************************************************************************
   Facility Capital Costs
*******************************************************************************

Boiler capital costs: $ 1,093,737
  Boiler #1 ( 36 k-lb stm/hr) cost: $ 364,579
  Boiler #2 ( 36 k-lb stm/hr) cost: $ 364,579
  Boiler #3 ( 36 k-lb stm/hr) cost: $ 364,579

Stack capital costs: $ 34,709

Building and service capital costs: $ 1,143,696
  Boiler house capital costs: $ 1,033,016
  Miscellaneous building costs: $ 110,680

Boiler Water Treatment System Capital Costs: $ 188,681
  Cost of zeolite softeners: $ 15,514
  Cost of dealkalizers: $ 101,706
  Cost of chemical injection skid: $ 22,037
  Cost of water lab: $ 22,037
  Cost of 1 deaerator: $ 27,385

Cost of boiler feedwater pumps: $ 18,757
Cost of condensate transfer pumps: $ 16,385

Cost of condensate storage tank: $ 5,934
Cost of long term oil storage: $ 201,113
  Cost of long term storage tanks: $ 163,255
  Cost of long term storage-other: $ 37,857

Cost of oil (day storage) pumps: $ 4,958
Cost of oil (day storage) heaters: $ 5,454
Cost of short term storage tanks: $ 16,098

Cost of oil unloading pumps: $ 14,544
Cost of [3] oil transfer pumps: $ 4,793
Cost of fire protection equipment: $ 44,075
Cost of 1 continuous blowdown tank: $ 845
Cost of 1 intermittent blowdown tank: $ 845
Compressor cost (2 - 30 Hp - 150 psig): $ 27,196

Cost of car puller and accessories: $ 22,037
Cost of rail tracks: $ 11,707

Site preparation cost: $ 3,223
Site improvement cost: $ 169,139

Total cost of mobile equipment: $ 42,973
  Cost of fork lift: $ 22,037
  Cost of pickup truck: $ 15,426
  Cost of power sweeper: $ 5,509

Cost of electric substation: $ 60,803
```

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 4
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Capital Costs, cont
****

Electrical costs: $ 131,896

Piping costs: $ 747,411

Instrumentation costs: $ 276,353

Spare parts cost: $ 24,321

Initial consumables: $ 8,512

Tools cost: $ 22,037

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 5
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Direct Costs
****

Direct costs: $ 1,485,804
Development permit cost: $ 60,803
Project contingency costs: $ 451,063
Construction management costs: $ 210,496
Engineering and design costs: $ 360,851
Owner management costs: $ 180,425
Startup cost: $ 222,163

****
Installed Capital Equipment Cost Summary
****

Total Capital Costs: $ 3,326,420
Total Direct labor cost: $ 837,303
Total Freight cost: $ 63,833
Total Bulk material cost: $ 531,946
Total Direct costs: $ 1,485,804

Plant installed cost: $ 6,245,307

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 6
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Operating Labor Requirements
****

Operation personnel requirements
plant manager: 1
plant engineer: 0
plant technician: 0
plant clerk: 0
plant secretary: 0
plant janitor: 0
operations operator: 4
operations assistant operator: 1
fuel storage operator equipment: 0
maintenance a mechanic: 1
maintenance a electrician: 1

Operating staff: 10

Annual Labor Costs: $ 514,498

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 7
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Yearly O & M Costs Summary
****

Annual boiler maintenance costs: $ 7,656
Annual insurance cost: $ 106,389
Maximum electrical consumption @ PMCR: 272 kW
Annual electricity usage: 794,786 kW-hr
Annual O & M (materials/supplies) costs: $ 40,343
Annual condensate make-up water cost: $ 25,113
Annual blowdown make-up water cost: $ 5,022
Annual facility washdown water cost: $ 2,340
Annual personnel water cost: $ 267
Annual zeolite softener water cost: $ 4,252
Annual chemicals cost: $ 787
Annual sanitary sewer cost: $ 2,559
Annual miscellaneous maintenance costs: $ 8,983
Study year water cost: $3.00/1000 gallon
1995 cost for distillate: 0.780 $/gallon
1995 cost for residual: 0.600 $/gallon
1995 cost for natural gas: 5.180 $/million Btu
1995 cost for electricity: 0.078 $/kW-hr
Annual consumables cost: $ 1,702
Annual spare parts cost: $ 3,648
Annual mobile equipment maintenance: $ 3,437
1999 Natural gas costs : $ 2,212,754
1999 Auxiliary Energy Costs : $ 63,767
1999 #2 fuel oil costs : $ 2,452,774

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 8
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Periodic Maintenance Costs Summary
****

Major boiler maintenance costs (every 15 years): $ 65,624
Major stack maintenance costs (every 10 years): $ 6,941
Major water treatment system maintenance costs (every 10 years): $ 52,749
Major deaerator maintenance costs (every 20 years): $ 6,846
Motor-driven feedwater pumps maint costs (every 15 years): $ 7,502
Centrifugal pump maint costs (every 18 years): $ 6,554
Sump pump maintenance costs (every 20 years): $ 6,016
Oil pump maintenance costs (every 5 years): $ 6,251
Periodic EPA permit testing/renewal costs (every 3 years): $ 30,000

Central Heating Plant Economics Evaluation Program -- Cost Analysis
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Economic Data Summary
****

Capital Equipment Escalation Factor: 1.102
based on Engineering News Record, Construction Cost Index: 5032.16

Non-Labor Operation & Maintenance Escalation Factor: 1.092
based on Chemical Engineering, M & S Index, Steam Power Comp: 935.60

Operation & Maintenance Labor Escalation Factor: 1.119
based on Engineering News Record, Skilled Labor Index: 4626.82

Construction Labor Escalation Factor: 1.024
based on Chemical Engineering, Construction Labor Index: 271.10

Annual Facility Output: 279,504 thousand lb steam
Steam enthalpy: 1195.6 Btu/lb
Inlet enthalpy: 88.0 Btu/lb
Annual Natural Gas Usage: 346 10^6 SCF
Heating plant efficiency: 80.8% natural gas
Discount Rate: 4 %
Year of Study: 1995
Years of Operation: 1999 - 2023
10% Investment Cost Exclusion IS NOT applied
Annual #2 Fuel Oil Usage: 2,711 10^3 gal
Heating plant efficiency: 84.1% #2 fuel oil

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 10
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Cash Flow Summary
****

Analysis using natural gas as primary fuel

1998 adjusted investment: 6,245,307 existing plant salvage: 0

Year	Boiler Fuel	Auxiliary Energy	Non-Energy O&M	Repair and Replacement
1999	2,212,754	63,767	580,270	0
2000	2,302,342	64,951	597,295	0
2001	2,396,397	66,055	597,295	30,000
2002	2,494,939	66,370	597,295	0
2003	2,584,525	66,844	597,295	6,251
2004	2,669,623	67,474	597,295	30,000
2005	2,759,210	68,341	597,295	0
2006	2,821,927	68,894	597,295	0
2007	2,898,069	69,564	597,295	30,000
2008	2,974,210	69,604	597,295	65,942
2009	3,090,686	69,880	597,295	0
2010	3,202,655	71,102	597,295	30,000
2011	3,260,197	71,536	597,295	0
2012	3,317,720	71,976	597,295	0
2013	3,375,262	72,419	597,295	109,378
2014	3,432,787	72,868	597,295	0
2015	3,490,327	73,322	597,295	0
2016	3,547,852	73,781	597,295	36,554
2017	3,605,394	74,245	597,295	0
2018	3,653,332	74,683	597,295	78,804
2019	3,701,285	75,125	597,295	30,000
2020	3,749,221	75,574	597,295	0
2021	3,797,158	76,028	597,295	0
2022	3,845,112	76,488	597,295	30,000
2023	3,893,049	76,953	597,295	6,251

2024 new plant salvage: 0

Central Heating Plant Economics Evaluation Program -- Cost Analysis
File: WVAR1 Type: New plant (NP)
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Life Cycle Cost Summary
****

Analysis using natural gas as primary fuel

+ PV 'Adjusted' Investment Costs	= $	5,552,055
+ PV Energy + Transportation Costs	= $	42,911,903
+ PV Annually Recurring O&M Costs	= $	8,280,674
+ PV Non-Annually Recurring Repair & Replacement	= $	250,552
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	56,995,185

Levelized Cost of Service (1999 start) = 12.772 $/MMBtu
Levelized Cost of Service (1999 start) = 15.270 $/1000 lb steam

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 12
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Cash Flow Summary
****

Analysis using #2 fuel oil as primary fuel

1998 adjusted investment: 6,245,307 existing plant salvage: 0

Year	Boiler Fuel	Auxiliary Energy	Non-Energy O&M	Repair and Replacement
1999	2,452,774	63,767	580,270	0
2000	2,545,266	64,951	597,295	0
2001	2,621,657	66,055	597,295	30,000
2002	2,690,006	66,370	597,295	0
2003	2,750,335	66,844	597,295	6,251
2004	2,802,602	67,474	597,295	30,000
2005	2,854,871	68,341	597,295	0
2006	2,899,096	68,894	597,295	0
2007	2,943,321	69,564	597,295	30,000
2008	2,991,589	69,604	597,295	65,942
2009	3,035,814	69,880	597,295	0
2010	3,067,978	71,102	597,295	30,000
2011	3,123,088	71,536	597,295	0
2012	3,178,198	71,976	597,295	0
2013	3,233,327	72,419	597,295	109,378
2014	3,288,436	72,868	597,295	0
2015	3,343,547	73,322	597,295	0
2016	3,398,655	73,781	597,295	36,554
2017	3,453,764	74,245	597,295	0
2018	3,499,696	74,683	597,295	78,804
2019	3,545,626	75,125	597,295	30,000
2020	3,591,556	75,574	597,295	0
2021	3,637,489	76,028	597,295	0
2022	3,683,401	76,488	597,295	30,000
2023	3,729,333	76,953	597,295	6,251

2024 new plant salvage: 0

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 13
File: WVAR1 Type: New plant (NP) 01/05/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Life Cycle Cost Summary
****

Analysis using #2 fuel oil as primary fuel

+ PV 'Adjusted' Investment Costs	= $	5,552,055
+ PV Energy + Transportation Costs	= $	43,074,246
+ PV Annually Recurring O&M Costs	= $	8,280,674
+ PV Non-Annually Recurring Repair & Replacement	= $	250,552
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	57,157,529

Levelized Cost of Service (1999 start) = 12.808 $/MMBtu
Levelized Cost of Service (1999 start) = 15.313 $/1000 lb steam

```
**********************************************************************************
**    Central Heating Plant Economics Evaluation Program              Page 1    **
**    File: WVARCOG1     Type: Cogeneration new plant (CG)          02/08/95    **
**    Desc: WATERVLIET ARSENAL                                                   **
**    Tech: Gas / Oil Fired Boiler                                               **
**********************************************************************************

State     : NY - New York
Location :  42d 43m -  73d 42m
County    :
Emission regulation region
#  0 -  State and federal only

Annual heating degree days:  6725

*************************** Boiler Characteristics ****************************

Type of heating system : Steam

Average Monthly Steam Flows (million Btu/hr)

              Jan      Feb      Mar      Apr      May      Jun
               59       65       56       35        8        4
              Jul      Aug      Sep      Oct      Nov      Dec
                3        4        5       35       49       61

Calculated PMCR: 125 thousand lb/hr steam      *** manual entry

Average Monthly Electrical Loads (kW)

              Jan      Feb      Mar      Apr      May      Jun
             7000     8000     7000     7000     7000     7000
              Jul      Aug      Sep      Oct      Nov      Dec
             8000     7000     7000     7000     7000     7000

Peak Monthly Electrical Loads (kW)

              Jan      Feb      Mar      Apr      May      Jun
             8000     9500     8000     8000     8000     8300
              Jul      Aug      Sep      Oct      Nov      Dec
             9500     8000     8000     8000     8000     8000

Maximum peak monthly electrical load: 9500 kW

Cogeneration efficiency: 30%
Steam required for peak: 83,726 lb/hr
Plant specified can meet steam requirements for peak

Boiler technology: Gas / Oil Fired Boiler

Boiler sizes (thousand lb steam/hr) :
         1:  42    2:  42    3:  42
```

```
**********************************************************************************
**   Central Heating Plant Economics Evaluation Program              Page 2    **
**   File: WVARCOG1     Type: Cogeneration new plant (CG)          02/08/95    **
**   Desc: WATERVLIET ARSENAL                                                  **
**   Tech: Gas / Oil Fired Boiler                                              **
**********************************************************************************


Natural gas composition - volume basis
    82.90 % Methane        0.00 % Ethylene      14.90 % Ethane
     0.00 % Propane        0.00 % Butane         0.00 % Hydrogen
     2.20 % Nitrogen       0.00 % Oxygen         0.00 % Hydrogen Sulfide (H2S)
     0.00 % Carbon Monoxide (CO)                 0.00 % Carbon Dioxide (CO2)
     1107 Btu/SCF Heating Value

Natural gas composition - weight basis
    73.70 % Carbon    22.94 % Hydrogen              0.00 % Oxygen
     0.00 % Sulfur     0.00 % Carbon Monoxide       3.36 % Inert gases (N2, CO2)
      22695 Btu/lb heating value

Boiler Operating Parameters -- Natural Gas
   Combustion air temp:  70 deg F      30 % relative humidity
   Flue gas temp: 350 deg F          3.00 % oxygen (dry basis)
   40.02 % combustibles
   10.25 % CO2                      86.73 % N2
   0.00481 lb/lb dry air            0.00772 mole/mole dry air
    14.94 % excess air              0.020 % combustibles

Boiler Performance -- Natural Gas
   Sensible dry gas loss:      5.370 %    Loss H2O vapor in air:      0.044 %
   Fuel H2O heat loss:         0.000 %    H2 comb H2O heat loss:     10.741 %
   Radiation heat loss:        1.849 %    Unaccounted for loss:       1.000 %
   Combustible gas heat loss:  0.064 %
   Boiler efficiency:         80.932 %

Fuel Oil #2 composition - weight basis
    87.40 % Carbon    12.50 % Hydrogen              0.00 % Oxygen
     0.00 % Nitrogen   0.10 % Sulfur                0.00 % Ash
     0.00 % Moisture
      18993 Btu/lb heating value
   0.856 Specific gravity

Boiler Operating Parameters -- Fuel Oil #2
   Combustion air temp:  70 deg F      30 % relative humidity
   Flue gas temp: 350 deg F          2.50 % oxygen (dry basis)
   50.02 % combustibles
   13.69 % CO2                      83.79 % N2
   0.00481 lb/lb dry air            0.00772 mole/mole dry air
    12.65 % excess air              0.020 % combustibles

Boiler Performance -- Fuel Oil #2
   Sensible dry gas loss:      5.775 %    Loss H2O vapor in air:      0.048 %
   Fuel H2O heat loss:         0.000 %    H2 comb H2O heat loss:      6.993 %
   Radiation heat loss:        1.849 %    Unaccounted for loss:       1.000 %
   Combustible gas heat loss:  0.068 %
   Boiler efficiency:         84.267 %
```

```
**********************************************************************************
**   Coal Fired Boiler Evaluation Program                          Page 3     **
**   File: WVARCOG1     Type: Cogeneration new plant (CG)        02/08/95     **
**   Desc: WATERVLIET ARSENAL                                                 **
**   Tech: Gas / Oil Fired Boiler                                             **
**********************************************************************************

************************* Boiler Performance @ PMCR ***************************
Blowdown    :   5 %

Temperature out of stack :   350 deg F
Steam pressure           :  600 psig
Steam temperature        :  750 deg F        enthalpy  : 1378.9 Btu/lb
Condensate return temp   :  150 deg F        enthalpy  :  118.0 Btu/lb
Makeup water temperature :   50 deg F        enthalpy  :   18.0 Btu/lb
Inlet water temperature  :  120 deg F        enthalpy  :   88.1 Btu/lb

********************** Area and Water Requirements @ PMCR **********************

Building size : 10500 sq ft              Condensate Return    :    75 %
Plant area    :  1.42 acres              Boiler house leakage :     2 %
Plant height  :    40 ft                 Water requirements   :   100 gpm (est)
Stack height  :    60 ft                 Railway track length :   125 ft
Sewer dischrg :    50 gpm (est)
```

```
********************************************************************************
**    Coal Fired Boiler Evaluation Program                          Page 4    **
**    File: WVARCOG1     Type: Cogeneration new plant (CG)        02/08/95    **
**    Desc: WATERVLIET ARSENAL                                               **
**    Tech: Gas / Oil Fired Boiler                                           **
********************************************************************************

************************ General Site Considerations ************************

Development and Construction

     Total:      0/    0       0%

================================================================================

Fuel Supply and Site Access

Gas purchase contracts:
  Score:   0

Oil supply contracts:
  Score:   0

     Total:      0/    0       0%

================================================================================

Ecology

     Total:      0/    0       0%

================================================================================

Social Considerations

     Total:      0/    0       0%

================================================================================

Facility Services

Condition of system is fair
Additional costs may be required to install a new distribution system.
These costs are not considered in the detailed evaluation program.
  Score:   3
```

```
**********************************************************************
**   Central Heating Plant Economics Evaluation Program        Page 5   **
**   File: WVARCOG1     Type: Cogeneration new plant (CG)    02/08/95   **
**   Desc: WATERVLIET ARSENAL                                          **
**   Tech: Gas / Oil Fired Boiler                                      **
**********************************************************************

Steam distribution system routing is medium
It may be difficult to incorporate the existing distribution system
into the new plant.  Additional costs may be required heavily modify
the existing distribution system.  These costs are not considered in
the new plant detailed evaluation section of this program.
  Score:   2

City water available: Yes
  Score:   5

     Total:    95/  145      65%

======================================================================


Waste Handling and Emissions

Local sewer system available: Yes
  Score:   5

     Total:    50/   50     100%

======================================================================


Military

     Total:     0/    0       0%

======================================================================


Cogeneration

Plant will operated for over 6000 hours per year
The facility will be operating enough to justify building a cogeneration
plant.
  Score:   5

The existing electricity distribution system IS
     compatible with a cogeneration system
  Score:   5

It IS NOT likely that energy demand will be curtailed
  Score:   5
```

```
**********************************************************************************
**    Central Heating Plant Economics Evaluation Program            Page 6    **
**    File: WVARCOG1     Type: Cogeneration new plant (CG)        02/08/95    **
**    Desc: WATERVLIET ARSENAL                                                **
**    Tech: Gas / Oil Fired Boiler                                            **
**********************************************************************************

The utility WILL maintain and repair interconnection facilities
  Score:   5

The utility MAY be cooperative in setting up the
     electrical interconnections and stand by power costs
Additional costs may be required to set up the electrical interconnections
and stand by power costs.  This should be further evaluated before
proceeding to a detailed evaluation.
  Score:   2

The electric utility DOES use coal as their primary fuel
Cogeneration may not be cost effective due to the local
availability of relativaly low cost electricity generated by coal.
  Score:   1

The facility's average electrical power / steam ratio is above 75 kWh/MBtu
Cogeneration may not be cost effective because a significant portion
of the base's electric requirements must still be purchased from
the local utility.  A more detailed analysis of the electrical and
thermal load curves should be performed prior to a detailed evavuation.
  Score:   5

Cost of electricity:   7.80 cents/kWh        Cost of coal:    5.10 $/Mbtu
The high cost of fuel may make cogeneration prohibitive.
The facility's electric load is below 25 MW
Due to small facility electric load mearurements it may not be
cost effective to cogenerate.
  Score:   1

The facility's load factor is above 40%
The load factor is sufficient to warrant cogeneration.
  Score:   5

The facility's annual electrical power / steam ratio is above 75 kWh/MBtu
Cogeneration may not be cost effective because a significant portion
of the base's electric requirements must still be purchased from
the local utility.  A more detailed analysis of the electrical and
thermal load curves should be performed prior to a detailed evavuation.
  Score:   5

PMCR is below 200 MMBtu output; facility is probably not suitable for cogenerat

     Total:   400/  550      72%

==================================================================================
```

```
**********************************************************************************
**    Central Heating Plant Economics Evaluation Program            Page 7    **
**    File: WVARCOG1     Type: Cogeneration new plant (CG)          02/08/95    **
**    Desc: WATERVLIET ARSENAL                                                 **
**    Tech: Gas / Oil Fired Boiler                                             **
**********************************************************************************
```

General Questions Summary

	Total	Max	Rating
Development and Construction	0	0	0
Fuel Supply and Site Access	0	0	0
Ecology	0	0	0
Social Considerations	0	0	0
Facility Services	95	145	65
Waste Handling and Emissions	50	50	100
Military	0	0	0
Cogeneration	400	550	72

Boiler technology rating: 10

Feasibility score: 10/10 = 100%

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 1
File: WVARCOG1 Type: Cogeneration new plant (CG) [illegible] 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler Follow Heat Load

****
Base and Plant Information
****

State: NY - New York Base DOE Region: 1
PMCR: 125,000 lb/hr steam Number of boilers: 3

Height of the plant: 40 ft
Building area: 10500 sq ft
Plant area: 1.42 acres

****
Facility Parameters
****

Capital Equipment Escalation Factor: 1.102 (5032.16/1995)
Non-Labor Operation & Maintenance Escalation Factor: 1.092 (935.60/1995)
Operation & Maintenance Labor Escalation Factor: 1.119 (4626.82/1995)
Construction Labor Escalation Factor: 1.024 (271.10/1995)

Annual electricity usage: 1,019,734 kW-hr

1995 cost for distillate: 0.780 $/gallon
1995 cost for residual: 0.600 $/gallon
1995 cost for natural gas: 5.180 $/million Btu
1995 cost for electricity: 0.078 $/kW-hr

Annual Facility Output: 278,784 thousand lb steam
278,784 thousand lb steam (incl cogen)
Annual Natural Gas Usage: 401 10^6 SCF
Heating plant efficiency: 80.9% natural gas
Year of Study: 1995
Years of Operation: 1999 - 2023
Annual #2 Fuel Oil Usage: 3,147 10^3 gal
Heating plant efficiency: 84.3% #2 fuel oil

****
Facility Capital Costs
****

Equipment		Cost	Equipment		Cost
Boiler:	$	1,553,656	Stack:	$	34,709
Building/service:	$	1,582,995	Cogen Equipment:	$	2,363,542
Water trtmnt:	$	645,440	Feedwtr pmps:	$	138,724
Cond xfr pmps:	$	18,658	Cond strg tnk:	$	6,293
Oil (long) storage:	$	245,946	Oil day strg pmp:	$	6,280
Oil heaters:	$	6,390	Oil day strg tanks:	$	18,151
Oil unload pumps:	$	14,544	Oil xfr pmps:	$	5,454
Fire protection:	$	44,075	Cont bldn tnk:	$	895
Intr bldn tnk:	$	895	Compressor:	$	27,196
Car puller:	$	22,037	Rail:	$	11,707
Site preparation:	$	3,911	Site improvements:	$	179,056

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 2
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Capital Costs, cont
****

Mobile equipment:	$ 42,973	Elec substation:	$ 95,663
Electrical:	$ 182,994	Piping:	$ 1,036,966
Instrumentation:	$ 383,416	Direct costs:	$ 3,084,850

****
Plant installed cost: $ 14,263,149

****
Facility Annual O & M and Energy Costs
****

Operating staff: 11
Annual Labor Costs: $ 544,914
Annual Year Non-Labor O & M Costs : $ 649,840
1999 Natural gas costs : $ 2,568,396
1999 Auxiliary Energy Costs : $ 81,815
1999 #2 fuel oil costs : $ 2,847,199

****
Periodic Major Maintenance Cost Summary
****

Time Interval	Cost	Time Interval	Cost
3 years	$ 30,000	5 years	$ 254,162
10 years	$ 250,358	15 years	$ 148,709
18 years	$ 7,463	20 years	$ 12,862
25 years	$ 6,498		

****
Facility Life Cycle Cost Summary
****

Analysis using natural gas as primary fuel

+ PV 'Adjusted' Investment Costs	= $ 12,679,887
+ PV Energy + Transportation Costs	= $ 49,927,858
+ PV Annually Recurring O&M Costs	= $ 9,005,485
+ PV Non-Annually Recurring Repair & Replacement	= $ 1,117,963
- PV Cogeneration Electricity Credit	= $ 38,725,304
+ PV Disposal Cost of Existing System	= $ 0
+ PV Disposal Cost of New/Retrofit Facility	= $ 0
Total Life Cycle Cost (1995)	= $ 34,005,891

Levelized Cost of Service (1999 start) = 6.6244 $/MMBtu
Levelized Cost of Service (1999 start) = 9.1344 $/1000 lb steam

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 3
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Life Cycle Cost Summary
****

Analysis using #2 fuel oil as primary fuel

+ PV 'Adjusted' Investment Costs	= $	12,679,887
+ PV Energy + Transportation Costs	= $	50,119,842
+ PV Annually Recurring O&M Costs	= $	9,005,485
+ PV Non-Annually Recurring Repair & Replacement	= $	1,117,963
- PV Cogeneration Electricity Credit	= $	38,725,304
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	34,197,875

Levelized Cost of Service (1999 start) = 6.6618 $/MMBtu
Levelized Cost of Service (1999 start) = 9.1859 $/1000 lb steam

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 1
File: WVARCOG1 Type: Cogeneration new plant (CG) Follow Elec Load 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler Follow Heat Load

****
Base Information
****

State: NY - New York Base DOE Region: 1
PMCR: 125,000 lb/hr steam Number of boilers: 3

Steam Properties: 600 psi (1378.9 Btu/lb)
Inlet water temp: 120 deg F enthalpy: 88.1 Btu/lb

****
Boiler Design Parameters
****

A mixed bed for condensate polishing IS REQUIRED
A dealkalizer unit IS NOT NEEDED

****
Cogeneration Subsystem Design Parameters
****

Average Steam Loads (1000 lb/hr)

	Jan	Feb	Mar	Apr	May	Jun
Heat/Proc:	59*	65*	56*	35*	8*	4*
Cogen Sys:	62	71	62	62	62	62
	Jul	Aug	Sep	Oct	Nov	Dec
Heat/Proc:	3*	4*	5*	35*	49*	61*
Cogen Sys:	71	62	62	62	62	62

Cogeneration efficiency: 30%
Cogen system sized for 84,000 lb steam/hr

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 2
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Plant Design Parameters --- Space Requirements
****

Height of the plant: 40 ft
Building area: 10500 sq ft
Plant area: 1.42 acres

****
Plant Design Parameters --- Water & Water Treatment Specifications
****

Feedwater flow: 263 gpm
Surface area of feedwater heater: 0 sq ft
Number of deaerators: 1
Number of resin vessels / train: 2
Number of mixed beds / train: 1
Boiler 1: 1 motor-driven feedwater pump -- 81 gpm
Boiler 2: 1 motor-driven feedwater pump -- 81 gpm
Boiler 3: 1 motor-driven feedwater pump -- 81 gpm
Number of condensate transfer pumps: 3
Condensate transfer pump size: 991 gpm

Condensate storage tank size: 4000 gallons
Number of long term oil storage tanks: 1
Capacity of one long term oil storage tank: 861000 gal
Number of oil (day storage) pumps: 3
Short term storage tank size: 4,779 gallons

Length of rail track: 125 ft
Annual personnel water use: 93,537 gallons

```
Central Heating Plant Economics Evaluation Program -- Cost Analysis      Page 3
File: WVARCOG1     Type: Cogeneration new plant (CG)                    02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

*******************************************************************************
   Facility Capital Costs
*******************************************************************************

Boiler capital costs: $ 1,553,656
  Boiler #1 ( 42 k-lb stm/hr) cost: $ 517,885
  Boiler #2 ( 42 k-lb stm/hr) cost: $ 517,885
  Boiler #3 ( 42 k-lb stm/hr) cost: $ 517,885

Stack capital costs: $ 34,709

Building and service capital costs: $ 1,582,995
  Boiler house capital costs: $ 1,446,222
  Miscellaneous building costs: $ 136,773

Cogeneration equipment capital costs: $ 2,363,542
  Cooling tower and condenser not required.  Heating uses all steam.
  Cost of feedwater heater: $ 5,511
  Cost of turbine generator: $ 2,358,031

Boiler Water Treatment System Capital Costs: $ 645,440
  Cost of demineralizers: $ 386,219
  Cost of mixed bed for condensate polishing: $ 154,704
  Cost of chemical injection skid: $ 33,056
  Cost of water lab: $ 44,075
  Cost of 1 deaerator: $ 27,385

Cost of boiler feedwater pumps: $ 138,724
Cost of condensate transfer pumps: $ 18,658

Cost of condensate storage tank: $ 6,293
Cost of long term oil storage: $ 245,946
  Cost of long term storage tanks: $ 202,231
  Cost of long term storage-other: $ 43,715

Cost of oil (day storage) pumps: $ 6,280
Cost of oil (day storage) heaters: $ 6,390
Cost of short term storage tanks: $ 18,151

Cost of oil unloading pumps: $ 14,544
Cost of [3] oil transfer pumps: $ 5,454
Cost of fire protection equipment: $ 44,075
Cost of 1 continuous blowdown tank: $ 895
Cost of 1 intermittent blowdown tank: $ 895
Compressor cost (2 - 30 Hp - 150 psig): $ 27,196

Cost of car puller and accessories: $ 22,037
Cost of rail tracks: $ 11,707

Site preparation cost: $ 3,911
Site improvement cost: $ 179,056

Total cost of mobile equipment: $ 42,973
```

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 4
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Capital Costs, cont
****

Cost of fork lift: $ 22,037
Cost of pickup truck: $ 15,426
Cost of power sweeper: $ 5,509

Cost of electric substation: $ 95,663
Electrical costs: $ 182,994

Piping costs: $ 1,036,966

Instrumentation costs: $ 383,416

Spare parts cost: $ 32,555

Initial consumables: $ 11,394

Tools cost: $ 28,648

```
Central Heating Plant Economics Evaluation Program -- Cost Analysis      Page 5
File: WVARCOG1     Type: Cogeneration new plant (CG)                    02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

*******************************************************************************
   Direct Costs
*******************************************************************************

Direct costs: $ 3,084,850
  Development permit cost: $ 81,389
  Project contingency costs: $ 1,037,361
  Construction management costs: $ 484,102
  Engineering and design costs: $ 829,889
  Owner management costs: $ 414,944
  Startup cost: $ 237,162


*******************************************************************************
   Installed Capital Equipment Cost Summary
*******************************************************************************

Total Capital Costs: $ 7,342,135
Total Direct labor cost: $ 2,241,343
Total Freight cost: $ 170,873
Total Bulk material cost: $ 1,423,946
Total Direct costs: $ 3,084,850

Plant installed cost: $ 14,263,149
```

```
Central Heating Plant Economics Evaluation Program -- Cost Analysis      Page 3
File: WVARCOG1     Type: Cogeneration new plant (CG)                    02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

*******************************************************************************
   Facility Operating Labor Requirements
*******************************************************************************

Operation personnel requirements
     plant manager: 1
     plant engineer: 0
     plant technician: 0
     plant clerk: 0
     plant secretary: 0
     plant janitor: 0
     operations operator: 4
     operations assistant operator: 1
     maintenance a mechanic: 1
     maintenance a electrician: 1

Operating staff: 11

Annual Labor Costs: $ 544,914
```

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 7
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Yearly O & M Costs Summary
****

Annual boiler maintenance costs: $ 10,875
Annual insurance cost: $ 284,789
Maximum electrical consumption @ PMCR: 370 kW
Annual electricity usage: 1,019,734 kW-hr
Annual O & M (materials/supplies) costs: $ 49,757
Annual condensate make-up water cost: $ 25,048
Annual blowdown make-up water cost: $ 5,009
Annual facility washdown water cost: $ 2,340
Annual personnel water cost: $ 280
Annual condensate polisher water cost: $ 910
Annual demineralizer water cost: $ 2,348
Annual mixed bed water cost: $ 910
Annual chemicals cost: $ 10,346
Annual sanitary sewer cost: $ 2,562
Annual miscellaneous maintenance costs: $ 10,903
Study year water cost: $3.00/1000 gallon
1995 cost for distillate: 0.780 $/gallon
1995 cost for residual: 0.600 $/gallon
1995 cost for natural gas: 5.180 $/million Btu
1995 cost for electricity: 0.078 $/kW-hr
Annual consumables cost: $ 2,278
Annual spare parts cost: $ 4,883
Annual mobile equipment maintenance: $ 3,437
1999 Natural gas costs : $ 2,568,396
1999 Auxiliary Energy Costs : $ 81,815
1999 #2 fuel oil costs : $ 2,847,199

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 8
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Periodic Maintenance Costs Summary
****

Major boiler maintenance costs (every 15 years): $ 93,219
Major stack maintenance costs (every 10 years): $ 6,941
Major cooling tower maintenance costs (every 15 years): $ 0
Turbine generator maintenance costs (every 5 years): $ 247,593
Major water treatment system maintenance costs (every 10 years): $ 243,415
Major deaerator maintenance costs (every 20 years): $ 6,846
Motor-driven feedwater pumps maint costs (every 15 years): $ 55,489
Centrifugal pump maint costs (every 18 years): $ 7,463
Circulation water pump maintenance costs (every 25 years): $ 6,497
Sump pump maintenance costs (every 20 years): $ 6,016
Oil pump maintenance costs (every 5 years): $ 6,569
Periodic EPA permit testing/renewal costs (every 3 years): $ 30,000

```
Central Heating Plant Economics Evaluation Program -- Cost Analysis      Page 9
File: WVARCOG1     Type: Cogeneration new plant (CG)                     02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

*******************************************************************************
   Economic Data Summary
*******************************************************************************

Capital Equipment Escalation Factor:  1.102
     based on Engineering News Record, Construction Cost Index: 5032.16

Non-Labor Operation & Maintenance Escalation Factor:  1.092
     based on Chemical Engineering, M & S Index, Steam Power Comp:  935.60

Operation & Maintenance Labor Escalation Factor:  1.119
     based on Engineering News Record, Skilled Labor Index: 4626.82

Construction Labor Escalation Factor:  1.024
     based on Chemical Engineering, Construction Labor Index:  271.10

Annual Facility Output: 278,784 thousand lb steam
                        278,784 thousand lb steam (incl cogen)
Steam enthalpy:         1378.9 Btu/lb
Inlet enthalpy:           88.0 Btu/lb
Annual Natural Gas Usage: 401 10^6 SCF
Heating plant efficiency: 80.9% natural gas
Discount Rate: 4 %
Cogeneration Electricity Credit Basis: 31,632,003 kW-hr
Year of Study: 1995
Years of Operation: 1999 - 2023
10% Investment Cost Exclusion IS NOT applied
Annual #2 Fuel Oil Usage: 3,147 10^3 gal
Heating plant efficiency: 84.3% #2 fuel oil
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Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 10
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Cash Flow Summary
****

Analysis using natural gas as primary fuel

1998 adjusted investment: 14,263,149 existing plant salvage: 0

Year	Boiler Fuel	Auxiliary Energy	Non-Energy O&M	Repair and Replacement	Cogen Elec Credit
1999	2,568,396	81,815	627,051	0	2,537,919
2000	2,672,382	83,334	649,840	0	2,585,010
2001	2,781,554	84,750	649,840	30,000	2,628,955
2002	2,895,935	85,155	649,840	0	2,641,508
2003	2,999,919	85,762	649,840	254,162	2,660,350
2004	3,098,694	86,572	649,840	30,000	2,685,453
2005	3,202,680	87,684	649,840	0	2,719,967
2006	3,275,477	88,393	649,840	0	2,741,952
2007	3,363,856	89,253	649,840	30,000	2,768,629
2008	3,452,235	89,304	649,840	504,520	2,770,201
2009	3,587,431	89,658	649,840	0	2,781,182
2010	3,717,397	91,226	649,840	30,000	2,829,845
2011	3,784,187	91,783	649,840	0	2,847,115
2012	3,850,955	92,347	649,840	0	2,864,602
2013	3,917,746	92,916	649,840	432,871	2,882,257
2014	3,984,517	93,492	649,840	0	2,900,130
2015	4,051,305	94,075	649,840	0	2,918,197
2016	4,118,075	94,663	649,840	37,463	2,936,457
2017	4,184,866	95,259	649,840	0	2,954,936
2018	4,240,508	95,821	649,840	517,382	2,972,352
2019	4,296,169	96,388	649,840	30,000	2,989,960
2020	4,351,808	96,964	649,840	0	3,007,810
2021	4,407,450	97,546	649,840	0	3,025,878
2022	4,463,112	98,136	649,840	30,000	3,044,188
2023	4,518,754	98,734	649,840	260,660	3,062,715

2024 new plant salvage: 0

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 11
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Life Cycle Cost Summary
****

Analysis using natural gas as primary fuel

+ PV 'Adjusted' Investment Costs	= $	12,679,887
+ PV Energy + Transportation Costs	= $	49,927,858
+ PV Annually Recurring O&M Costs	= $	9,005,485
+ PV Non-Annually Recurring Repair & Replacement	= $	1,117,963
- PV Cogeneration Electricity Credit	= $	38,725,304
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	34,005,891

Levelized Cost of Service (1999 start) = 6.6244 $/MMBtu
Levelized Cost of Service (1999 start) = 9.1344 $/1000 lb steam

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 12
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Cash Flow Summary
****

Analysis using #2 fuel oil as primary fuel

1998 adjusted investment: 14,263,149 existing plant salvage: 0

Year	Boiler Fuel	Auxiliary Energy	Non-Energy O&M	Repair and Replacement	Cogen Elec Credit
1999	2,847,199	81,815	627,051	0	2,537,919
2000	2,954,564	83,334	649,840	0	2,585,010
2001	3,043,240	84,750	649,840	30,000	2,628,955
2002	3,122,580	85,155	649,840	0	2,641,508
2003	3,192,610	85,762	649,840	254,162	2,660,350
2004	3,253,283	86,572	649,840	30,000	2,685,453
2005	3,313,956	87,684	649,840	0	2,719,967
2006	3,365,293	88,393	649,840	0	2,741,952
2007	3,416,630	89,253	649,840	30,000	2,768,629
2008	3,472,660	89,304	649,840	504,520	2,770,201
2009	3,523,996	89,658	649,840	0	2,781,182
2010	3,561,333	91,226	649,840	30,000	2,829,845
2011	3,625,305	91,783	649,840	0	2,847,115
2012	3,689,277	92,347	649,840	0	2,864,602
2013	3,753,271	92,916	649,840	432,871	2,882,257
2014	3,817,242	93,492	649,840	0	2,900,130
2015	3,881,215	94,075	649,840	0	2,918,197
2016	3,945,185	94,663	649,840	37,463	2,936,457
2017	4,009,157	95,259	649,840	0	2,954,936
2018	4,062,474	95,821	649,840	517,382	2,972,352
2019	4,115,790	96,388	649,840	30,000	2,989,960
2020	4,169,106	96,964	649,840	0	3,007,810
2021	4,222,425	97,546	649,840	0	3,025,878
2022	4,275,720	98,136	649,840	30,000	3,044,188
2023	4,329,039	98,734	649,840	260,660	3,062,715

2024 new plant salvage: 0

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 13
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Life Cycle Cost Summary
****

Analysis using #2 fuel oil as primary fuel

+ PV 'Adjusted' Investment Costs	= $	12,679,887
+ PV Energy + Transportation Costs	= $	50,119,842
+ PV Annually Recurring O&M Costs	= $	9,005,485
+ PV Non-Annually Recurring Repair & Replacement	= $	1,117,963
- PV Cogeneration Electricity Credit	= $	38,725,304
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	34,197,875

Levelized Cost of Service (1999 start) = 6.6618 $/MMBtu
Levelized Cost of Service (1999 start) = 9.1859 $/1000 lb steam

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 1
File: WVARCOGI Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler Operate All Year

****
Base and Plant Information
****

State: NY - New York Base DOE Region: 1
PMCR: 125,000 lb/hr steam Number of boilers: 3

Height of the plant: 40 ft
Building area: 10500 sq ft
Plant area: 1.42 acres

****
Facility Parameters
****

Capital Equipment Escalation Factor: 1.102 (5032.16/1995)
Non-Labor Operation & Maintenance Escalation Factor: 1.092 (935.60/1995)
Operation & Maintenance Labor Escalation Factor: 1.119 (4626.82/1995)
Construction Labor Escalation Factor: 1.024 (271.10/1995)

Annual electricity usage: 1,649,523 kW-hr

1995 cost for distillate: 0.780 $/gallon
1995 cost for residual: 0.600 $/gallon
1995 cost for natural gas: 5.180 $/million Btu
1995 cost for electricity: 0.078 $/kW-hr

Annual Facility Output: 278,784 thousand lb steam
555,864 thousand lb steam (incl cogen)
Annual Natural Gas Usage: 800 10^6 SCF
Heating plant efficiency: 80.9% natural gas
Year of Study: 1995
Years of Operation: 1999 - 2023
Annual #2 Fuel Oil Usage: 6,275 10^3 gal
Heating plant efficiency: 84.3% #2 fuel oil

****
Facility Capital Costs
****

Equipment		Cost	Equipment		Cost
Boiler:	$	1,553,656	Stack:	$	34,709
Building/service:	$	1,582,995	Cogen Equipment:	$	2,797,500
Water trtmnt:	$	645,440	Feedwtr pmps:	$	138,724
Cond xfr pmps:	$	18,658	Cond strg tnk:	$	6,293
Oil (long) storage:	$	245,946	Oil day strg pmp:	$	6,280
Oil heaters:	$	6,390	Oil day strg tanks:	$	18,151
Oil unload pumps:	$	14,544	Oil xfr pmps:	$	5,454
Fire protection:	$	44,075	Cont bldn tnk:	$	895
Intr bldn tnk:	$	895	Compressor:	$	27,196
Car puller:	$	22,037	Rail:	$	11,707
Site preparation:	$	3,911	Site improvements:	$	179,056

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 2
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Capital Costs, cont
****

Mobile equipment:	$ 42,973	Elec substation:	$ 95,663
Electrical:	$ 182,994	Piping:	$ 1,036,966
Instrumentation:	$ 383,416	Direct costs:	$ 3,258,433

****
Plant installed cost: $ 15,162,965

****
Facility Annual O & M and Energy Costs
****

Operating staff: 11
Annual Labor Costs: $ 544,914
Annual Year Non-Labor O & M Costs : $ 918,445
1999 Natural gas costs : $ 5,121,093
1999 Auxiliary Energy Costs : $ 132,345
1999 #2 fuel oil costs : $ 5,676,996

****
Periodic Major Maintenance Cost Summary
****

Time Interval	Cost	Time Interval	Cost
3 years	$ 30,000	5 years	$ 254,162
10 years	$ 250,358	15 years	$ 180,601
18 years	$ 7,463	20 years	$ 12,862
25 years	$ 6,498		

****
Facility Life Cycle Cost Summary
****

Analysis using natural gas as primary fuel

+ PV 'Adjusted' Investment Costs	= $ 13,479,820
+ PV Energy + Transportation Costs	= $ 99,080,786
+ PV Annually Recurring O&M Costs	= $ 12,735,865
+ PV Non-Annually Recurring Repair & Replacement	= $ 1,133,706
- PV Cogeneration Electricity Credit	= $ 77,213,909
+ PV Disposal Cost of Existing System	= $ 0
+ PV Disposal Cost of New/Retrofit Facility	= $ 0
Total Life Cycle Cost (1995)	= $ 49,216,269

Levelized Cost of Service (1999 start) = 9.5874 $/MMBtu
Levelized Cost of Service (1999 start) = 13.220 $/1000 lb steam

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 3
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Life Cycle Cost Summary
****

Analysis using #2 fuel oil as primary fuel

+ PV 'Adjusted' Investment Costs	= $	13,479,820
+ PV Energy + Transportation Costs	= $	99,463,582
+ PV Annually Recurring O&M Costs	= $	12,735,865
+ PV Non-Annually Recurring Repair & Replacement	= $	1,133,706
- PV Cogeneration Electricity Credit	= $	77,213,909
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	49,599,065

Levelized Cost of Service (1999 start) = 9.6620 $/MMBtu
Levelized Cost of Service (1999 start) = 13.322 $/1000 lb steam

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 1
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler Operate All Year

****
Base Information
****

State: NY - New York Base DOE Region: 1
PMCR: 125,000 lb/hr steam Number of boilers: 3

Steam Properties: 600 psi (1378.9 Btu/lb)
Inlet water temp: 120 deg F enthalpy: 88.1 Btu/lb

****
Boiler Design Parameters
****

A mixed bed for condensate polishing IS REQUIRED
A dealkalizer unit IS NOT NEEDED

****
Cogeneration Subsystem Design Parameters
****

Average Steam Loads (1000 lb/hr)

	Jan	Feb	Mar	Apr	May	Jun
Heat/Proc:	59	65	56	35	8	4
Cogen Sys:	62*	71*	62*	62*	62*	62*
	Jul	Aug	Sep	Oct	Nov	Dec
Heat/Proc:	3	4	5	35	49	61
Cogen Sys:	71*	62*	62*	62*	62*	62*

Cogeneration efficiency: 30%
Cogen system sized for 84,000 lb steam/hr

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 2
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Plant Design Parameters --- Space Requirements
****

Height of the plant: 40 ft
Building area: 10500 sq ft
Plant area: 1.42 acres

****
Plant Design Parameters --- Water & Water Treatment Specifications
****

Cooling tower-condenser water circulation rate: 9,336 gpm
Feedwater flow: 263 gpm
Surface area of feedwater heater: 0 sq ft
Number of deaerators: 1
Number of resin vessels / train: 2
Number of mixed beds / train: 1
Boiler 1: 1 motor-driven feedwater pump -- 81 gpm
Boiler 2: 1 motor-driven feedwater pump -- 81 gpm
Boiler 3: 1 motor-driven feedwater pump -- 81 gpm
Number of condensate transfer pumps: 3
Condensate transfer pump size: 991 gpm

Condensate storage tank size: 4000 gallons
Number of long term oil storage tanks: 1
Capacity of one long term oil storage tank: 861000 gal
Number of oil (day storage) pumps: 3
Short term storage tank size: 4,779 gallons

Length of rail track: 125 ft
Annual cooling tower makeup water use: 67,256,332 gallons
Annual personnel water use: 93,537 gallons

```
Central Heating Plant Economics Evaluation Program -- Cost Analysis      Page 3
File: WVARCOG1     Type: Cogeneration new plant (CG)                     02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

*******************************************************************************
   Facility Capital Costs
*******************************************************************************

Boiler capital costs: $ 1,553,656
  Boiler #1 ( 42 k-lb stm/hr) cost: $ 517,885
  Boiler #2 ( 42 k-lb stm/hr) cost: $ 517,885
  Boiler #3 ( 42 k-lb stm/hr) cost: $ 517,885

Stack capital costs: $ 34,709

Building and service capital costs: $ 1,582,995
  Boiler house capital costs: $ 1,446,222
  Miscellaneous building costs: $ 136,773

Cogeneration equipment capital costs: $ 2,797,500
  Cost of condenser: $ 115,036
  Cost of cooling tower: $ 318,921
  Cost of feedwater heater: $ 5,511
  Cost of turbine generator: $ 2,358,031

Boiler Water Treatment System Capital Costs: $ 645,440
  Cost of demineralizers: $ 386,219
  Cost of mixed bed for condensate polishing: $ 154,704
  Cost of chemical injection skid: $ 33,056
  Cost of water lab: $ 44,075
  Cost of 1 deaerator: $ 27,385

Cost of boiler feedwater pumps: $ 138,724
Cost of condensate transfer pumps: $ 18,658

Cost of condensate storage tank: $ 6,293
Cost of long term oil storage: $ 245,946
  Cost of long term storage tanks: $ 202,231
  Cost of long term storage-other: $ 43,715

Cost of oil (day storage) pumps: $ 6,280
Cost of oil (day storage) heaters: $ 6,390
Cost of short term storage tanks: $ 18,151

Cost of oil unloading pumps: $ 14,544
Cost of [3] oil transfer pumps: $ 5,454
Cost of fire protection equipment: $ 44,075
Cost of 1 continuous blowdown tank: $ 895
Cost of 1 intermittent blowdown tank: $ 895
Compressor cost (2 - 30 Hp -- 150 psig): $ 27,196

Cost of car puller and accessories: $ 22,037
Cost of rail tracks: $ 11,707

Site preparation cost: $ 3,911
Site improvement cost: $ 179,056
```

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 4
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Capital Costs, cont
****

Total cost of mobile equipment: $ 42,973
Cost of fork lift: $ 22,037
Cost of pickup truck: $ 15,426
Cost of power sweeper: $ 5,509

Cost of electric substation: $ 95,663
Electrical costs: $ 182,994

Piping costs: $ 1,036,966

Instrumentation costs: $ 383,416

Spare parts cost: $ 32,555

Initial consumables: $ 11,394

Tools cost: $ 28,648

```
Central Heating Plant Economics Evaluation Program -- Cost Analysis      Page 5
File: WVARCOG1     Type: Cogeneration new plant (CG).                    02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

********************************************************************************
   Direct Costs
********************************************************************************

Direct costs: $ 3,258,433
  Development permit cost: $ 81,389
  Project contingency costs: $ 1,102,455
  Construction management costs: $ 514,479
  Engineering and design costs: $ 881,964
  Owner management costs: $ 440,982
  Startup cost: $ 237,162


********************************************************************************
   Installed Capital Equipment Cost Summary
********************************************************************************

Total Capital Costs: $ 7,776,093
Total Direct labor cost: $ 2,412,110
Total Freight cost: $ 183,892
Total Bulk material cost: $ 1,532,435
Total Direct costs: $ 3,258,433

Plant installed cost: $ 15,162,965
```

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 6
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Facility Operating Labor Requirements
****

Operation personnel requirements
plant manager: 1
plant engineer: 0
plant technician: 0
plant clerk: 0
plant secretary: 0
plant janitor: 0
operations operator: 4
operations assistant operator: 1
maintenance a mechanic: 1
maintenance a electrician: 1

Operating staff: 11

Annual Labor Costs: $ 544,914

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Central Heating Plant Economics Evaluation Program -- Cost Analysis      Page 7
File: WVARCOG1     Type: Cogeneration new plant (CG)                    02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

*******************************************************************************
   Yearly O & M Costs Summary
*******************************************************************************

Annual boiler maintenance costs: $ 10,875
Annual insurance cost: $ 306,487
Maximum electrical consumption @ PMCR: 370 kW
  Annual electricity usage: 1,649,523 kW-hr
Annual O & M (materials/supplies) costs: $ 318,362
  Annual condensate make-up water cost: $ 49,944
  Annual blowdown make-up water cost: $ 9,988
  Annual facility washdown water cost: $ 2,340
  Annual cooling tower water cost: $ 201,768
  Annual personnel water cost: $ 280
  Annual condensate polisher water cost: $ 1,815
  Annual demineralizer water cost: $ 4,682
  Annual mixed bed water cost: $ 1,815
  Annual chemicals cost: $ 21,308
  Annual sanitary sewer cost: $ 24,417
Annual miscellaneous maintenance costs: $ 10,903
Study year water cost: $3.00/1000 gallon
1995 cost for distillate:  0.780 $/gallon
1995 cost for residual:  0.600 $/gallon
1995 cost for natural gas:  5.180 $/million Btu
1995 cost for electricity:  0.078 $/kW-hr
  Annual consumables cost: $ 2,278
  Annual spare parts cost: $ 4,883
  Annual mobile equipment maintenance: $ 3,437
1999 Natural gas costs  : $   5,121,093
1999 Auxiliary Energy Costs       : $     132,345
1999 #2 fuel oil costs  : $   5,676,996
```

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 8
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Periodic Maintenance Costs Summary
****

Major boiler maintenance costs (every 15 years): $ 93,219
Major stack maintenance costs (every 10 years): $ 6,941
Major cooling tower maintenance costs (every 15 years): $ 31,892
Turbine generator maintenance costs (every 5 years): $ 247,593
Major water treatment system maintenance costs (every 10 years): $ 243,415
Major deaerator maintenance costs (every 20 years): $ 6,846
Motor-driven feedwater pumps maint costs (every 15 years): $ 55,489
Centrifugal pump maint costs (every 18 years): $ 7,463
Circulation water pump maintenance costs (every 25 years): $ 6,497
Sump pump maintenance costs (every 20 years): $ 6,016
Oil pump maintenance costs (every 5 years): $ 6,569
Periodic EPA permit testing/renewal costs (every 3 years): $ 30,000

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 9
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Economic Data Summary
****

Capital Equipment Escalation Factor: 1.102
based on Engineering News Record, Construction Cost Index: 5032.16

Non-Labor Operation & Maintenance Escalation Factor: 1.092
based on Chemical Engineering, M & S Index, Steam Power Comp: 935.60

Operation & Maintenance Labor Escalation Factor: 1.119
based on Engineering News Record, Skilled Labor Index: 4626.82

Construction Labor Escalation Factor: 1.024
based on Chemical Engineering, Construction Labor Index: 271.10

Annual Facility Output: 278,784 thousand lb steam
555,864 thousand lb steam (incl cogen)
Steam enthalpy: 1378.9 Btu/lb
Inlet enthalpy: 88.0 Btu/lb
Annual Natural Gas Usage: 800 10^6 SCF
Heating plant efficiency: 80.9% natural gas
Discount Rate: 4 %
Cogeneration Electricity Credit Basis: 63,070,663 kW-hr
Year of Study: 1995
Years of Operation: 1999 - 2023
10% Investment Cost Exclusion IS NOT applied
Annual #2 Fuel Oil Usage: 6,275 10^3 gal
Heating plant efficiency: 84.3% #2 fuel oil

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 10
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Cash Flow Summary
****

Analysis using natural gas as primary fuel

1998 adjusted investment: 15,162,965 existing plant salvage: 0

Year	Boiler Fuel	Auxiliary Energy	Non-Energy O&M	Repair and Replacement	Cogen Elec Credit
1999	5,121,093	132,345	895,656	0	5,060,326
2000	5,328,431	134,801	918,445	0	5,154,220
2001	5,546,108	137,092	918,445	30,000	5,241,842
2002	5,774,169	137,747	918,445	0	5,266,871
2003	5,981,502	138,730	918,445	254,162	5,304,440
2004	6,178,449	140,039	918,445	30,000	5,354,493
2005	6,385,786	141,838	918,445	0	5,423,309
2006	6,530,934	142,985	918,445	0	5,467,145
2007	6,707,152	144,376	918,445	30,000	5,520,335
2008	6,883,369	144,458	918,445	504,520	5,523,471
2009	7,152,936	145,031	918,445	0	5,545,366
2010	7,412,072	147,568	918,445	30,000	5,642,393
2011	7,545,245	148,469	918,445	0	5,676,829
2012	7,678,373	149,381	918,445	0	5,711,696
2013	7,811,547	150,301	918,445	464,763	5,746,897
2014	7,944,679	151,233	918,445	0	5,782,533
2015	8,077,848	152,176	918,445	0	5,818,559
2016	8,210,979	153,128	918,445	37,463	5,854,965
2017	8,344,153	154,091	918,445	0	5,891,811
2018	8,455,097	155,000	918,445	517,382	5,926,537
2019	8,566,078	155,918	918,445	30,000	5,961,646
2020	8,677,018	156,849	918,445	0	5,997,237
2021	8,787,962	157,791	918,445	0	6,033,262
2022	8,898,945	158,746	918,445	30,000	6,069,769
2023	9,009,888	159,712	918,445	260,660	6,106,710

2024 new plant salvage: 0

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 11
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Life Cycle Cost Summary
****

Analysis using natural gas as primary fuel

+ PV 'Adjusted' Investment Costs	= $	13,479,820
+ PV Energy + Transportation Costs	= $	99,080,786
+ PV Annually Recurring O&M Costs	= $	12,735,865
+ PV Non-Annually Recurring Repair & Replacement	= $	1,133,706
- PV Cogeneration Electricity Credit	= $	77,213,909
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	49,216,269

Levelized Cost of Service (1999 start) = 9.5874 $/MMBtu
Levelized Cost of Service (1999 start) = 13.220 $/1000 lb steam

Central Heating Plant Economics Evaluation Program -- Cost Analysis Page 12
File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

****
Cash Flow Summary
****

Analysis using #2 fuel oil as primary fuel

1998 adjusted investment: 15,162,965 existing plant salvage: 0

Year	Boiler Fuel	Auxiliary Energy	Non-Energy O&M	Repair and Replacement	Cogen Elec Credit
1999	5,676,996	132,345	895,656	0	5,060,326
2000	5,891,070	134,801	918,445	0	5,154,220
2001	6,067,879	137,092	918,445	30,000	5,241,842
2002	6,226,075	137,747	918,445	0	5,266,871
2003	6,365,707	138,730	918,445	254,162	5,304,440
2004	6,486,681	140,039	918,445	30,000	5,354,493
2005	6,607,657	141,838	918,445	0	5,423,309
2006	6,710,016	142,985	918,445	0	5,467,145
2007	6,812,378	144,376	918,445	30,000	5,520,335
2008	6,924,094	144,458	918,445	504,520	5,523,471
2009	7,026,453	145,031	918,445	0	5,545,366
2010	7,100,898	147,568	918,445	30,000	5,642,393
2011	7,228,452	148,469	918,445	0	5,676,829
2012	7,356,005	149,381	918,445	0	5,711,696
2013	7,483,602	150,301	918,445	464,763	5,746,897
2014	7,611,153	151,233	918,445	0	5,782,533
2015	7,738,708	152,176	918,445	0	5,818,559
2016	7,866,257	153,128	918,445	37,463	5,854,965
2017	7,993,809	154,091	918,445	0	5,891,811
2018	8,100,118	155,000	918,445	517,382	5,926,537
2019	8,206,424	155,918	918,445	30,000	5,961,646
2020	8,312,730	156,849	918,445	0	5,997,237
2021	8,419,042	157,791	918,445	0	6,033,262
2022	8,525,307	158,746	918,445	30,000	6,069,769
2023	8,631,618	159,712	918,445	260,660	6,106,710

2024 new plant salvage: 0

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File: WVARCOG1 Type: Cogeneration new plant (CG) 02/08/95
Desc: WATERVLIET ARSENAL
Tech: Gas / Oil Fired Boiler

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Life Cycle Cost Summary
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Analysis using #2 fuel oil as primary fuel

+ PV 'Adjusted' Investment Costs	= $	13,479,820
+ PV Energy + Transportation Costs	= $	99,463,582
+ PV Annually Recurring O&M Costs	= $	12,735,865
+ PV Non-Annually Recurring Repair & Replacement	= $	1,133,706
- PV Cogeneration Electricity Credit	= $	77,213,909
+ PV Disposal Cost of Existing System	= $	0
+ PV Disposal Cost of New/Retrofit Facility	= $	0
Total Life Cycle Cost (1995)	= $	49,599,065

Levelized Cost of Service (1999 start) = 9.6620 $/MMBtu
Levelized Cost of Service (1999 start) = 13.322 $/1000 lb steam