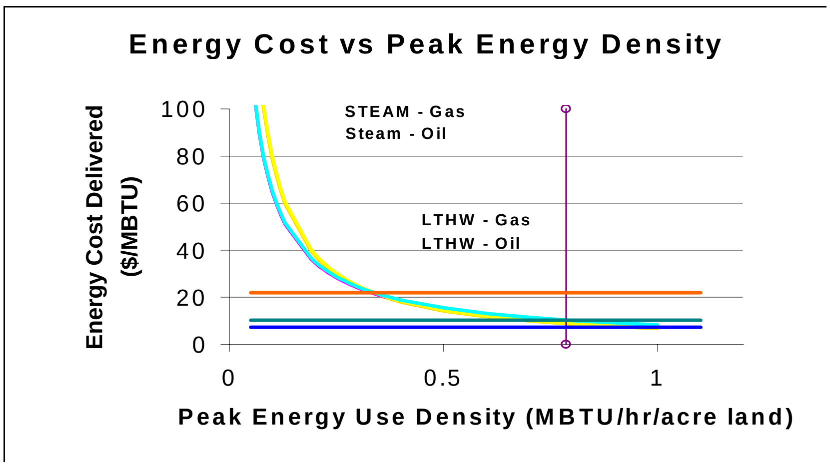
US Army Corps
of Engineers
Construction Engineering
Research Laboratories

USACERL Technical Report 99/23
January 1999

Energy Supply Options for Modernizing Army Heating Systems

Michael K. Brewer, Thomas E. Durbin, Chris Dilks, Roch A. Ducey, Vicki L. Van Blaricum, William T. Brown, William R. Taylor, Mark Imel, Vincent F. Hock, and Martin J. Savoie



Most Army central heating plants (CHPs) are about 30 years old. Many are nearing the end of their expected lives and experience poor combustion, low thermal efficiencies, and reliability problems. The most common solution for faulty CHP equipment is to replace it with the same technology. In some cases, however, the solution is to replace the large central system with many smaller, distributed gas-fired boiler systems.

Although modernization of equipment can help avoid the high cost of the air pollution control equipment required for new energy supply facilities, the economic benefits gained from the early modernization programs have changed the life extension philosophy at most utilities. Utilities now view modernization as a long-term strategy or an ongoing policy for maintenance of and investment in existing power plants, not simply as a way to avoid the high cost of air pollution equipment.

This report describes a screening tool and procedures to evaluate energy supply options to modernize or decentralize CHPs. The screening tool is to be used for a first level analysis of the suitability of central or decentralized plants using basic economic, climate, and real property data. If warranted, a more detailed conceptual analysis can be conducted which would then be the basis for initiating an energy supply implementation plan at the site. These guidelines do not represent a specific modernization program but rather a process to be adapted to specific needs at the Major Army Command and installation levels.

SF 298

Foreword

This study was conducted for U.S. Army Corps of Engineers (USACE) under Project 4A162784AT45, “Energy and Energy Conservation;” Work Unit UL-XC7, "Advanced Energy Supply Technology." The technical monitor was Tim Gordon, CEMP-ET.

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 Michael K. Brewer. Martin J. Savoie is Acting Chief, CECER-UL-U; Dr. John T. Bandy is Operations Chief, CECER-UL. The USACERL technical editor was Linda L. Wheatley, Technical Information Team.

Dr. Michael J. O'Connor is Director of USACERL.

Contents

List of Figures and Tables

Figures

Tables

1 Introduction

Background

Most Army central heating plants (CHPs) are about 30 years old; many are nearing the end of their expected lives and experience poor combustion, low thermal efficiencies, and reliability problems. The root cause of these problems is frequently overlooked. Because of its age, the most common solution for faulty equipment is to replace it with the same technology. In some cases, the solution is to replace the CHP with smaller, distributed gas-fired boiler systems. This action is frequently taken without a thorough evaluation of the energy supply strategy.

Private industry has been interested in optimizing its thermal energy supply methods for many years. To compete in the global market, companies continually evaluate all facets of their operation to look for opportunities to reduce cost and improve quality. The cost and reliability of energy for an operation must be controlled to maintain profitability. For example, DuPont has had a formal boiler life extension program since 1959 (Perkins 1986). This program was developed to formalize periodic inspections and repairs in greater detail than standard annual maintenance and overhauls, and was designed for boilers ranging from small, low-pressure heating boilers for warehouses to 325,000 pounds per hour (lb/h) pulverized coal-fired boilers and larger oil- and gas-fired boilers. Interest in modernization has also increased since the Clean Air Act (CAA) was promulgated in 1972. Modernization can help avoid the high cost of air pollution control equipment required for new energy supply facilities. The economic benefits gained from the early modernization programs changed the life extension philosophy at most utilities. Utilities now view modernization as a long-term strategy or an ongoing policy for maintenance of and investment in existing power plants, not simply as a way to avoid the high cost of air pollution equipment (Electric Power Research Institute [EPRI] 1987).

With the increased cost of managing and operating central coal fired plants, several industries are switching to gas-fired central boilers or decentralized boilers. A few companies have also outsourced the thermal energy supply utilities to third party contractors to allow the organization to focus its capital on core business functions. At Dupont's Louisville plant, a coal-fired cogeneration plant with steam-drive chillers was decommissioned and replaced with package gas-fired boilers and electric-motor chillers. Although DuPont engineering was reluctant to analyze a decentralized option due to the cost of gas, after considering all other costs such as labor, pollution prevention, and business cycle flexibility, they concluded that the package boiler option gave the best value to the company shareholders. It is interesting to note that, although DuPont had capital available for implementing the package boiler project, the return on investment could not compete with other investment opportunities in the plant process. As a result, DuPont used third party financing from institutions looking for low risk, low return (6 to 8 percent) investments (Dean 1998).

Objective

The overall objective of this project was to develop a screening tool and procedures to evaluate energy supply options to modernize or decentralize CHPs. The guidelines do not represent a specific modernization program but rather a process to be adapted to specific needs at the Major Army Command (MACOM) and installation levels. The screening tool is to be used for a first level analysis of the suitability of central or decentralized plants using basic economic, climate, and real property data. The number of data inputs should be small enough to be acquired in one or two telephone calls. The conceptual analysis guideline is a procedure to calculate the desirability of several energy supply options at a site. The conceptual analysis results would then be the basis for initiating an energy supply implementation plan at the site.

Approach

Historic, economic, regulatory, and market factors that have driven private industry and public utilities toward modernization and decentralization were reviewed to assess their applicability to the operating environment for Army CHPs. A screening tool was then developed in a spreadsheet to calculate cost curves of various central and decentralized heating systems. Next, a conceptual analysis process was developed for more detailed economic and design evaluation of energy supply technologies using HEATMAP* and a thermal and economic modeling tool.

---

* See p 22 for a description of HEATMAP.

Mode of Technology Transfer

The findings of this research effort will help focus CERL's research efforts for the Army's Modernization Technologies for Central Heating Plants program. The tools developed in this research also were used to support the Army Chief of Staff for Installation Management (ACSIM) CHP modernization program.

It is recommended that the results be used to update Army guidance documents, including Architect and Engineers Instructions (AEIs), Army Regulation (AR) 420-49, *Heating, Energy Selection and Fuel Storage, Distribution, and Dispensing Systems* and Technical Manual (TM) 5-650, *Repairs and Utilities: Central Boiler Plants*.

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 sq ft	=	0.093 m^2
1 gal	=	3.78 L
1 lb	=	0.453 kg
1 psi	=	6.89 kPa
°F	=	(°C x 1.8) + 32

2 Thermal and Economic Factors

Thermal Factors

Many of the Army CHPs were constructed in the 1940s–50s. The prevailing plant design relied on low-cost solid fuel (coal), a large well-trained labor pool, and few pollution control systems. Additionally, dual fuel security was a top concern, especially after the national coal strike in the late 1950s. Plants needed to have large stockpiles of fuel and the ability to switch fuels to keep the base heated. If coal is the primary fuel, a central plant is the more efficient and cleaner than many small hand-fired boilers. Steam generated at the plant could be piped to the buildings for "clean, dust-free" heat. A central plant also requires a smaller total boiler capacity because of the diversity of peak loads among a collection of buildings. Central steam plants also make possible the production of electricity for the base.

With the growth of the gas industry and the increase in emission control requirements, gas-fired boilers have replaced most of the coal-fired systems. Central gas-fired boilers still offer the possibility of dual-fueled systems as most of these systems can be ordered with both oil and gas burners. However, the gas-fired central plants now must compete against small unattended gas boilers, water heaters, and furnaces. Often the higher costs of uninterruptible natural gas (30 to 40 percent price premium) can be offset by the reductions in skilled labor and elimination of distribution system losses.

To assess the desirability of CHPs versus decentralized heating plants, the energy use density needs to be considered. The energy supply problem is solved by correctly balancing the losses of moving the steam and hot water through the distribution system against the inefficiencies of oversized or cycling decentralized conversion equipment. Marketing and feasibility studies in North America and northern Europe have shown that high peak energy use density (MBtu/hr/acre) and high load factor are important factors for ensuring profitable district heating plant projects (Bloomquist 1987). As cited by Bloomquist, Wahlman reports that, in general, district heating plants are favorable at densities greater than 0.7 MBtu/hr/acre, possible at 0.28 to 0.7 MBtu/hr/acre and unfavorable or questionable at less than 0.28 MBtu/hr/acre.

Economic Factors

CHP modernization or decentralization projects require cost analysis to determine if they make economic sense. Cost-effectiveness analyses need to be done on a life-cycle cost basis, which, for DoD projects, requires a 25-yr project life. For *central plants*, several economic issues need to be considered:

- ***High maintenance/low reliability***—Many DoD CHP boilers are 30 years old, or more, and are pushing performance limits. The older, less reliable boilers have higher maintenance costs and increased potential for failure, increasing the need to consider either construction of a new boiler unit or modernization of the existing unit.

- ***High cost of capital to build new unit***—Costs of complying with environmental, siting, and safety regulations add to the construction cost of new CHP units. Modernization programs have the potential advantage of lowering capital investment since existing units are merely retrofitted and upgraded.

- ***Poor performance of existing CHP***—System optimization tasks may need to be undertaken. Incorporating advances in boiler system design may become a cost-effective means to improve system performance.

- ***Distribution system maintenance***—The steam and condensate system requires an aggressive maintenance program and a reliable water treatment system. A steam trap life span is only 2 to 5 years depending on its type and location in the system.

- ***Three-shift operations***—Depending on the jurisdiction, certain boiler sizes (usually industrial sizes) require attendants. The jurisdiction may require at least two personnel in a boiler plant if it is considered a hazardous materials space. A staff of 10 to 13 operating personnel may be needed just to meet the attendance and safety regulations.

For *decentralized plants*, the following issues need to be considered:

- ***Boiler safety equipment maintenance***—Every boiler will have at least one safety valve and fuel train requiring maintenance. Maintenance on the safety system cannot be deferred. A fixed amount of maintenance is required on a commercial or industrial boiler regardless of its size.

- ***Firm gas price fluctuations***—Smaller boilers will only be fueled with gas. Firm (uninterruptible) priced gas will cost 30 to 40 percent more than the locally available, interruptible gas supply.
- ***Contractor support***—In most areas, a larger pool of contractors will be qualified to operate and maintain smaller commercial sized boilers than for larger industrial-size boilers.

3 Policy Factors

Several policy issues set the framework for energy supply in addition to the thermal and economic factors. Regulatory, fuel security, and program funding issues frequently impact the feasibility of modernization or decentralization.

Regulatory Forces

Regulatory forces may have two types of effects on an existing CHP: regulations may require an upgrade of the CHP, or regulations may make decentralization preferable to upgrading or building a new CHP. Regulations that affect CHP operation include environmental compliance regulations, siting clearances for new units, and safety code regulations.

Environmental regulations include the amended CAA, which applies more stringent emissions limits on particulate matter, sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), air toxins, and volatile organic compounds (VOCs). Additionally, the CAA calls for the complete phaseout of chlorinated fluorocarbons (CFCs) and certain other stratospheric ozone-depleting substances. CHP combustion produces SO_2 and NOx in amounts that vary with fuel type. Since natural gas is the primary fuel used at most DoD installations, NOx emission is the primary pollutant.

Utilities, industry, and the military face the same regulatory forces. The differences lie in the magnitude of pollution potential and in the ease of obtaining siting clearances. Utility fossil-fired plants tend to have higher annual fuel input than industrial or military plants, which may lead to more concern about pollution at utility plants. New utility projects require new site clearances that require action from several regulatory bodies. Industrial and military projects, however, tend to be on sites under their respective control.

Fuel Security

CHPs provide the opportunity to fire multiple fuels. If a burner conversion or upgrade is needed, it is easier to modify a few boilers at a central plant than 100 or so small boilers throughout the system. If oil capability is needed to augment natural gas, it is easier to manage a few centrally located oil storage tanks than a large number of small tanks. Small decentralized boilers are almost always gas fired, although a few electric boilers may provide point-of-use hot water or steam. These small gas-fired boilers will need an uninterruptible gas supply unless the site can permit the space to be unheated. As mentioned earlier, the price premium for firm (uninterruptible) gas is 30 to 40 percent above the available interruptible gas price. Figure 1 shows the fluctuations of gas and oil prices. The firm gas prices may vary as much as $2/MBtu over the course of a year (EIA 1998). Base managers need to account for the price risk when analyzing the feasibility of decentralizing or modernizing a CHP.

Policy Forces

Many policies within the DoD and the Army affect energy supply planning. These policies can be broadly categorized as base realignment and closure (BRAC), energy legislation, privatization, and project authorization.

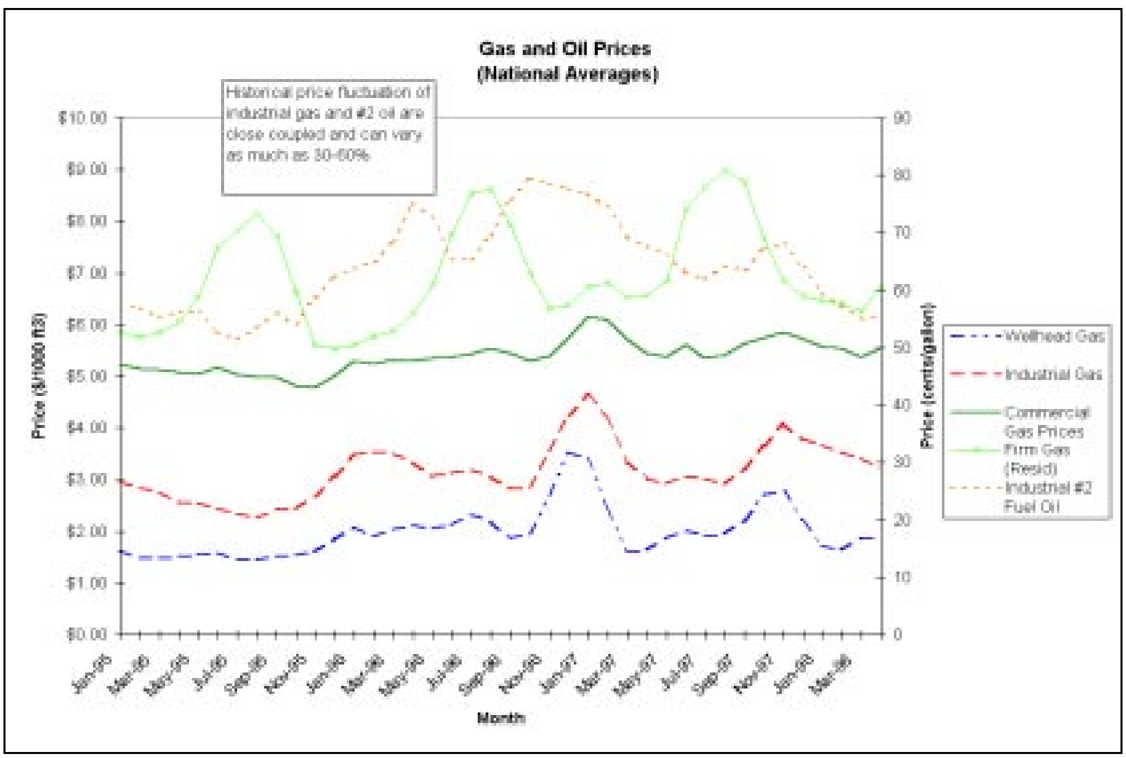


Figure 1. Historical gas and oil prices.

Base Realignment and Closure

The BRAC Commission was chartered on 3 May 1988 to develop recommendations for improving the effectiveness of military installations through realignment of missions and base closures. As of March 1993, BRAC had identified over 400 military installations for realignment or closure. Realignments add or remove activities from an installation that may ultimately change the installation's energy demands.

Energy Legislation

The Energy Policy Act of 1992 (Public Law [PL] 102-486) Subtitle F, *Federal Agency Energy Management*, establishes several Federal agency goals and requirements. It amends sections of the National Energy Conservation Policy Act to reflect and supplement goals and requirements established in Executive Order 12759, *Federal Energy Management*. It contains provisions regarding energy management requirements, life-cycle cost methodology, budget treatment for energy conservation measures, incentives for Federal agencies, reporting requirements, new technology demonstrations, and agency surveys of energy savings potential. The DoD establishes guidelines for meeting Federal energy goals with Defense Energy Program Policy Memorandums (DEPPMs) such as DEPPM 91-2, *Implementing Defense Energy Management Goals*. The Army issues memorandums to support Department of Defense (DoD) goals.

Privatization

AR 420-49 has been revised and requires life-cycle cost analysis and comparison of Army-owned heating plants and systems with private and municipal alternatives. Additionally, the Defense Reform Initiative (DRI 1997) states, “By January 1, 2000, the Department will privatize all utility systems (electric, water, waste water and natural gas) except those needed for unique security reasons or when privatization is uneconomical.” Although boiler plants are not listed in the DRI, it can be inferred that, if economical and feasible, privatizing thermal utilities would support the DRI’s intent, which is to divest DoD of activities not directly related to the main function of the military services, that function being to sustain combat operations.

Project Authorization

Authorization policies are probably the most important because they dictate how most energy projects will be developed. The following steps summarize the project decision sequence:

- Project originated at DoD installation.
- U.S. Army Corps of Engineers (USACE) district office does the project design.
- MACOM does a technical review of the project design, which covers project viability, project need based on its justification, and project economics (life-cycle cost). The MACOM reviews all projects, regardless of the project cost. They review the design at the 35, 65, and 95 percent completion stages.
- Onsite personnel and Architect and Engineer (A&E) contractors are used to implement the projects. Onsite personnel capabilities vary from installation to installation.

4 Energy Supply Methodology

Overview

Because the energy supply and use, heating plant performance requirements, and operational needs of each installation present different demands on modernization programs, the planning process guidelines presented here do not attempt to specify a single approach for modernizing all CHPs. Rather, these guidelines are intended to be general. The guidelines were developed by reviewing the literature by industry and performing modernization studies at Army installations. The guidelines identify a process that typically meets the needs of most Army and DoD installations.

The process provides for two levels of analysis. The first screening analysis quantifies thermal and economic parameters for the whole base. The second level is a more detailed analysis of plausible energy supply scenarios. Figure 2 is a flowchart of the energy supply analysis process.

Initiate Development of a Modernization Program

Modernization is a multidiscipline activity. It requires input and cooperation of design engineers, plant operation and maintenance managers, construction experts, economic and financial analysts, environmental analysts, energy and fuel purchase policymakers, research and development groups, equipment life analysts, and several levels of management.

To develop a program plan, a modernization team must develop program objectives, review and analyze certain system data, and provide resources for carrying out program activities. In addition, formal review and analyses are required of the Army's present and future energy supply and demand forecasts, the Army's energy policy, energy market forces, and many other factors that affect the overall "business" environment within the Army.

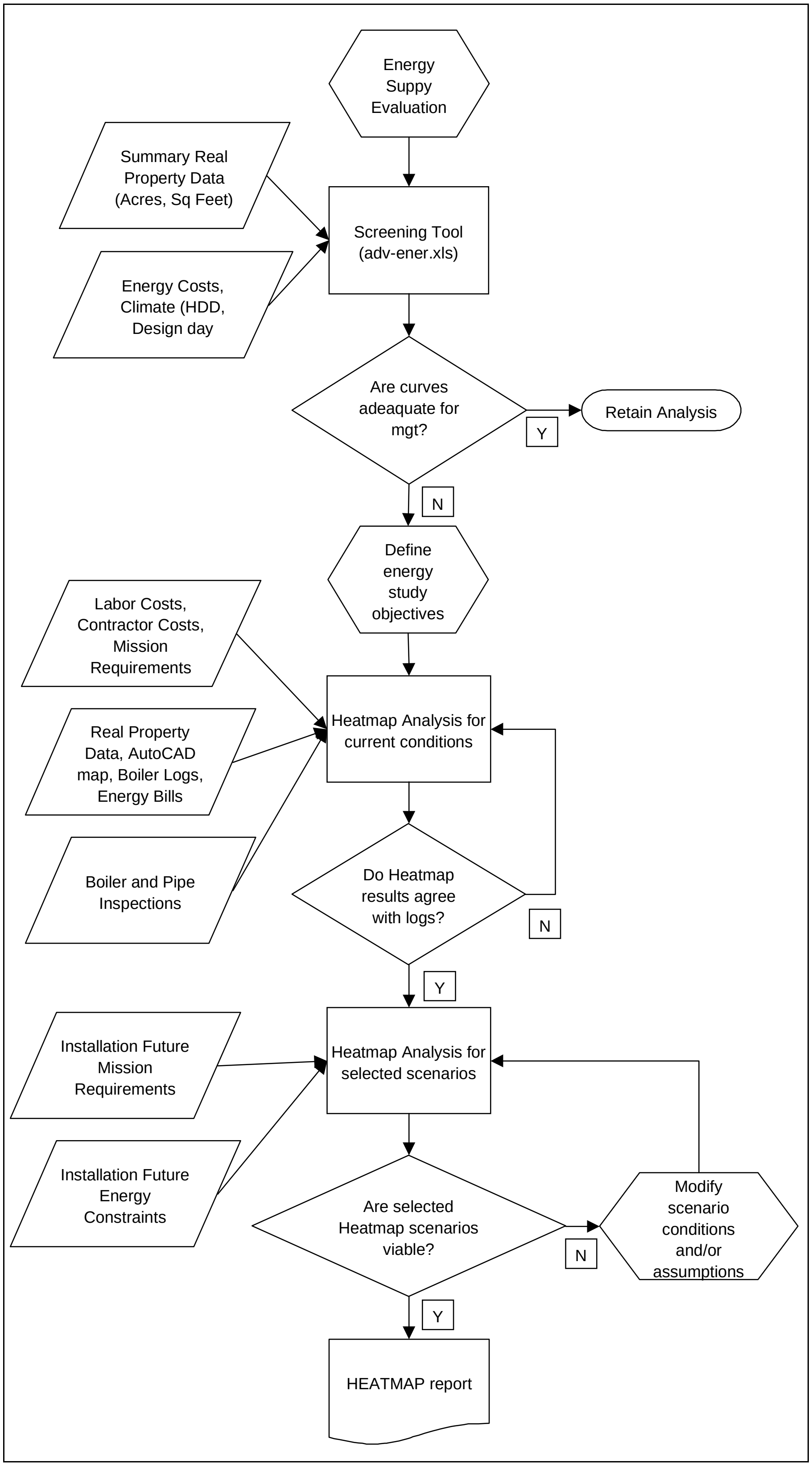


Figure 2. Energy supply analysis.

Define Program Objectives

Establishing the modernization program objective at the earliest possible stage is very important since it will guide development of the policies and tactical decisions to be made later in the program. The objective should be discussed among team members, and all members should understand what is expected from the modernization program. Examples of objective statements for modernization programs include:

- The objective of this modernization program is to systematically assess the condition of the major equipment at the Army's CHPs to ensure efficient and reliable operation of the plants beyond their designed life. Capacity improvements or efficiency improvements are not a part of this modernization program.

- The objective of this modernization program is to extend the lives of the Fort's central heating plants so they can operate safely, reliably, and cost effectively beyond their original design life.

- The objective of the modernization program is to extend the lives of central heating plants beyond their original design life while improving reliability, availability, efficiency, and environmental safety at installations where the heating and cooling demand is expected to increase by over "X" percent over the next "Y" years.

In addition, the objective statement should define the:

- desired technical and economic performance for the refurbished equipment

- desired fuel purchase policy (e.g., centralized vs distributed)

- difference between fuel cost and nonfuel operations and maintenance (O&M) costs

- specific environmental goals that must be met

- preference between purchase of new equipment or a technically equivalent repair option with higher expected O&M costs.

However, at this planning stage, the objective statement should not indicate how these objectives should be met. For example, the statement should not specify the timing of life extension or whether the life extension should include modernization or equipment upgrade. The timing and the need for modernization or equipment upgrade can be assessed more accurately at the installation or plant planning levels.

Establish Program Resource Requirements and Schedule

It is important to set achievable goals for the initial planning study, to set ample time for gathering and evaluating the required data, and to determine the required and available resources. Developing costs and schedules for installations with one or more CHPs and several potential modernization projects could become very cumbersome and difficult to manage. It may be advisable to attempt first to identify previously implemented life extension projects at DoD's CHPs or similar projects. An initial planning study would be undertaken for a selected number of installations based on information from these projects. As cost and scheduling information is integrated with the base and heat plant planning issues for these installations, a revised program could be developed to address the next few installations that could logically be developed for modernization.

Evaluate Technical and Economic Feasibility of Alternatives

At this planning level, the main questions are: what options should be considered, which plants should receive modernization first, and what are the technical and economic benefits and risks associated with the proposed actions? To answer these questions, three activities may have to be pursued. First, a visual inspection of the plants may have to be performed. Second, the operators and maintenance personnel may have to be interviewed. Third, the O&M procedures may have to be reviewed to identify potential systems, subsystems, or equipment that would require repair, replacement, upgrade, or refurbishment. In addition, alternatives to modernization must be identified in accordance with the program objective. Preliminary concept drawings must be developed when needed. Cost estimates for new equipment must be developed. Capital and operating costs must be estimated, and economic analyses must be performed for each alternative. The result of these analyses can then be used to rank various alternatives based either on economic merit alone or in conjunction with other factors.

Rank and Select Alternatives

Ranking methodologies consistent with the program goals should be developed for ranking, prioritizing, and selecting energy supply alternatives. The ranking methodology needs to consider the accuracy and quality of available information collected for each possible alternative so as not to bias the analysis.

Energy Supply Screening Tool

The energy supply screening tool was developed to quickly calculate cost curves for several energy supply options. As mentioned above, the energy use density is a significant parameter for determining the profitability of a central or decentralized heat system. The cost curve for decentralized boilers is level for practical purposes. The cost of heat from a boiler serving a remote building is not much different than the cost of heating an urban building. Costs may differ due to variations in labor and material prices, but any effect due to heat transfer or heat loss is minimal. However, there will be different costs for different sized boilers. In general, as equipment is scaled up or down the price varies about 70 percent of the magnitude of the equipment size. Also, for a boiler or hot water heater of any size, there will be a minimum fixed maintenance cost for the safety components. Another price premium on small boilers is due to the oversizing of the decentralized equipment to provide redundancy.

The cost of a central plant on a per-MBtu-delivered basis will sharply escalate as the buildings are more dispersed in the heating district. The flow and heat losses of the distribution system will consume the economy of scale savings from having larger central boilers. Ideally, for the same climate and fuel cost, the cost of a central plant in a densely built heat district will approach the cost of a very large decentralized boiler.

Figure 3 shows the curves calculated for Fort Eustis, VA. The central plant cost curves for low temperature hot water (LTHW) are slightly lower than the steam cost curves, because the thermal losses for hot water systems are less. Electrical costs will be increased, however, due to the need for more pumping power.

The cost curves were developed by analyzing the costs at eight Army CHPs. HEATMAP studies were conducted at the sites to calculate capital and operational costs. These studies were calibrated against plant logs so the heat losses at the site climate were realistic. Next, the eight data sets were run at three different uniform fuel costs to develop a characteristic curve as a function of fuel price and energy density. The HEATMAP study sets were next analyzed across five climates from the range of 2,000 to 10,000 heating degree days (HDD). More general cost equations were developed that predict the energy cost as a function of energy use density, climate, and fuel cost.

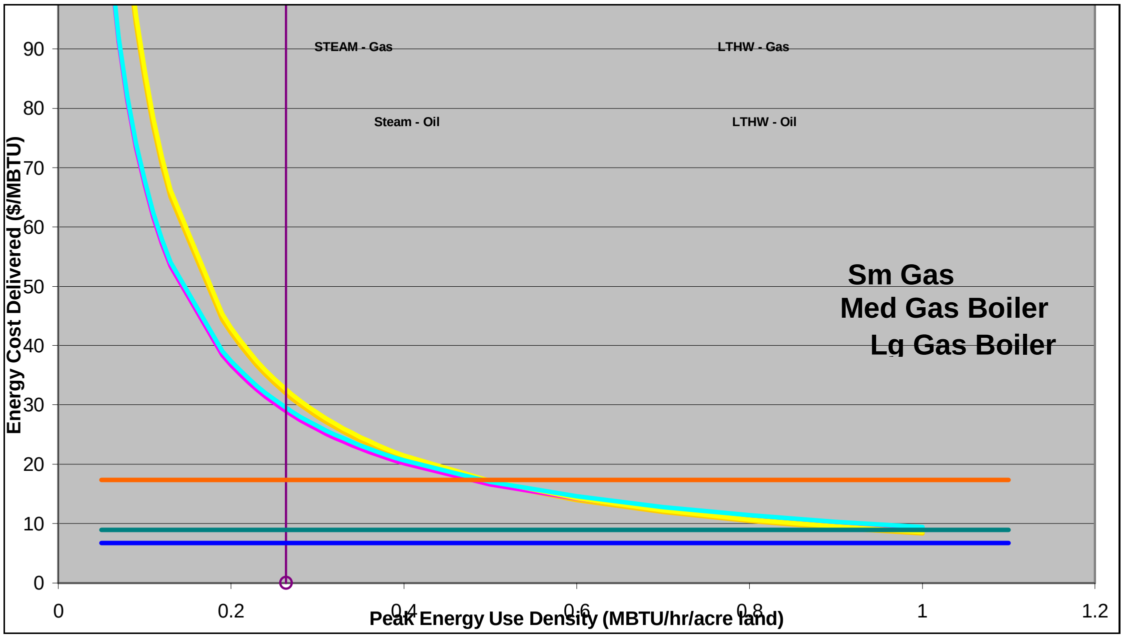


Figure 3. Energy cost versus peak energy density.

Conceptual Analysis Tool

If a more detailed study is needed, conceptual analysis using HEATMAP is conducted. HEATMAP analysis requires some basic building information such as area, type, and function. As described in Figure 2, the evaluation team will need to collect basic equipment condition and performance information. Monthly boiler logs and daily logs from a few load defining days such as peak winter load, minimum summer load, peak summer load, and holiday peak loads are usually sufficient for analysis. Due to the lack of a gauge calibration program at some locations, the evaluation team needs to scrutinize the logs for accuracy. Sometimes the only reliable measurement of plant load is the fuel consumption data.

HEATMAP

HEATMAP is a computerized system that provides a fast and reliable means for modeling the operation and economics of district heating and cooling (DHC) systems. HEATMAP graphically models the thermal, hydraulic, and economic characteristics of a DHC system. Its ease of use stems from the reliance on many preloaded data libraries. Default data are sufficient to get an analysis completed with only partial site data. As more detailed data are discovered, the model can be updated quickly. Additionally, almost all of the underlying library data is visible to the analyst if needed.

Although primarily designed to model proposed DHC systems, HEATMAP functions equally well in modeling existing systems. HEATMAP will take information related to the study area, production plants, and distribution network, and size the district heating and cooling system to meet thermal requirements. HEATMAP will optimize the mechanical facilities associated with DHC (i.e., pipe size and plant size). In addition, HEATMAP has the ability to model building loads and to determine the environmental impact of various DHC options. HEATMAP uses actual information, where available, and provides engineering estimates elsewhere.

HEATMAP is a standalone program that interfaces with the proprietary software AutoCAD 13c4 or 14 and LFLOW-2F. Figure 4 shows a HEATMAP AutoCAD interface screen.

The AutoCAD program provides a means for graphically representing the DHC system. Figures 5 through 6 show how, within an AutoCAD "map" of an installation, the user can identify and locate consumers, production plants, and existing or proposed distribution lines. The LFLOW-2F program then models and analyzes the distribution system operation based on the map developed with the AutoCAD program (refer to Figure 7).

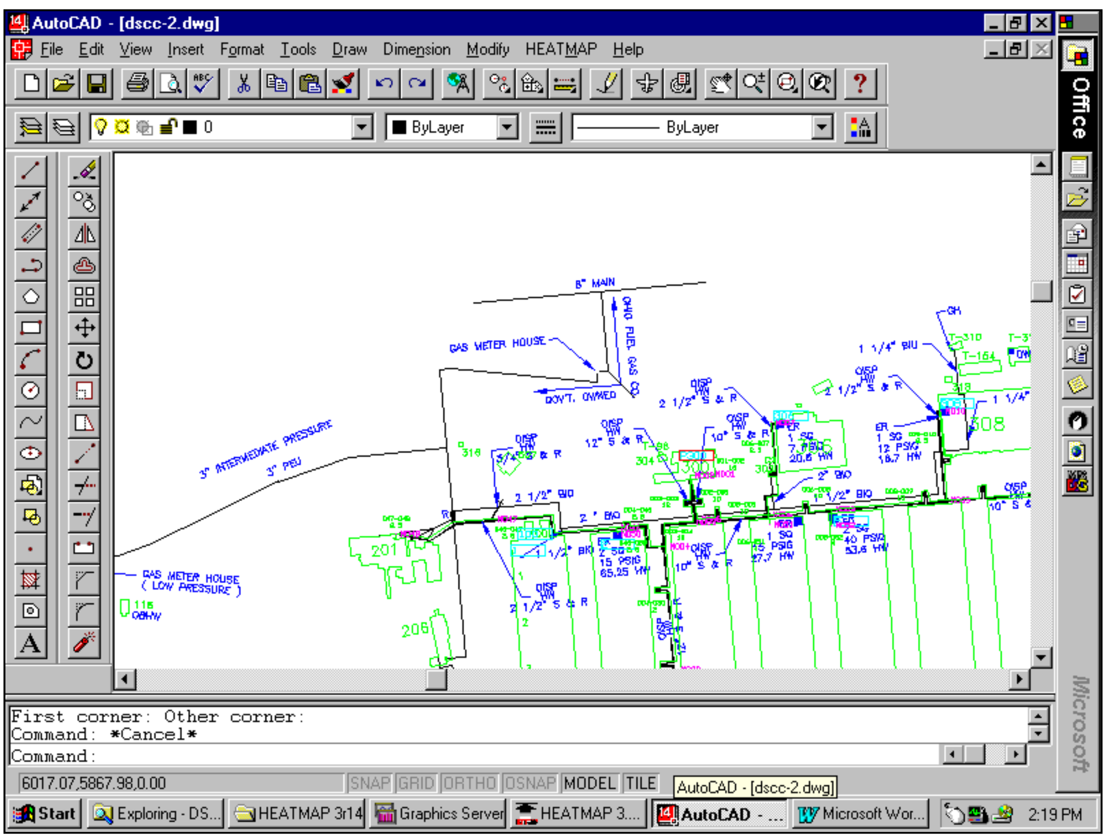


Figure 4. HEATMAP AutoCAD interface.

HEATMAP was developed by the Washington State Energy Office (WSEO) at Washington State University (WSU) in conjunction with several public and private organizations. USACERL is a partner with WSU/WSEO in the continuing development and enhancement of the HEATMAP program. WSU/WSEO also is developing modules for gas, water, wastewater, and electricity. The gas module, GASMAP will be particularly useful for conducting central versus decentral heat system analysis. These modules will operate together as a suite called UTILITYMAP. UTILITYMAP promises to enhance the evaluation of utility supply and delivery options by combining several analysis tools into one package.

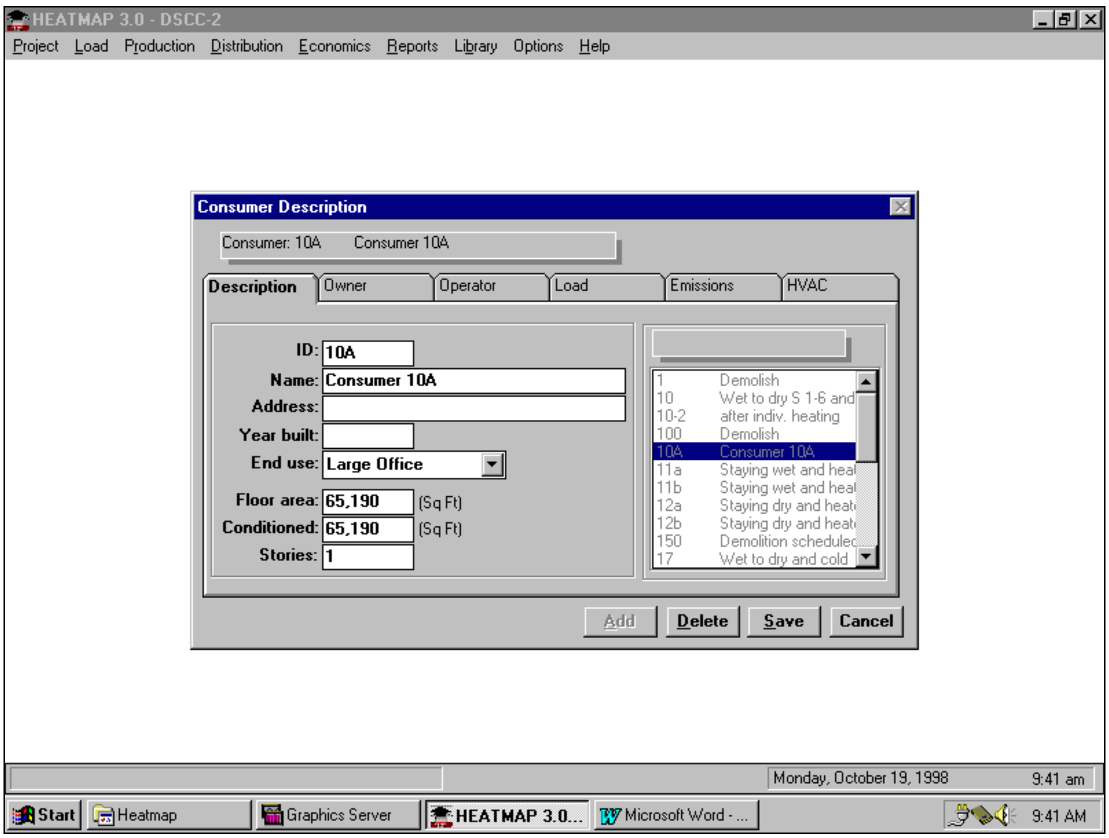


Figure 5. HEATMAP consumer interface.

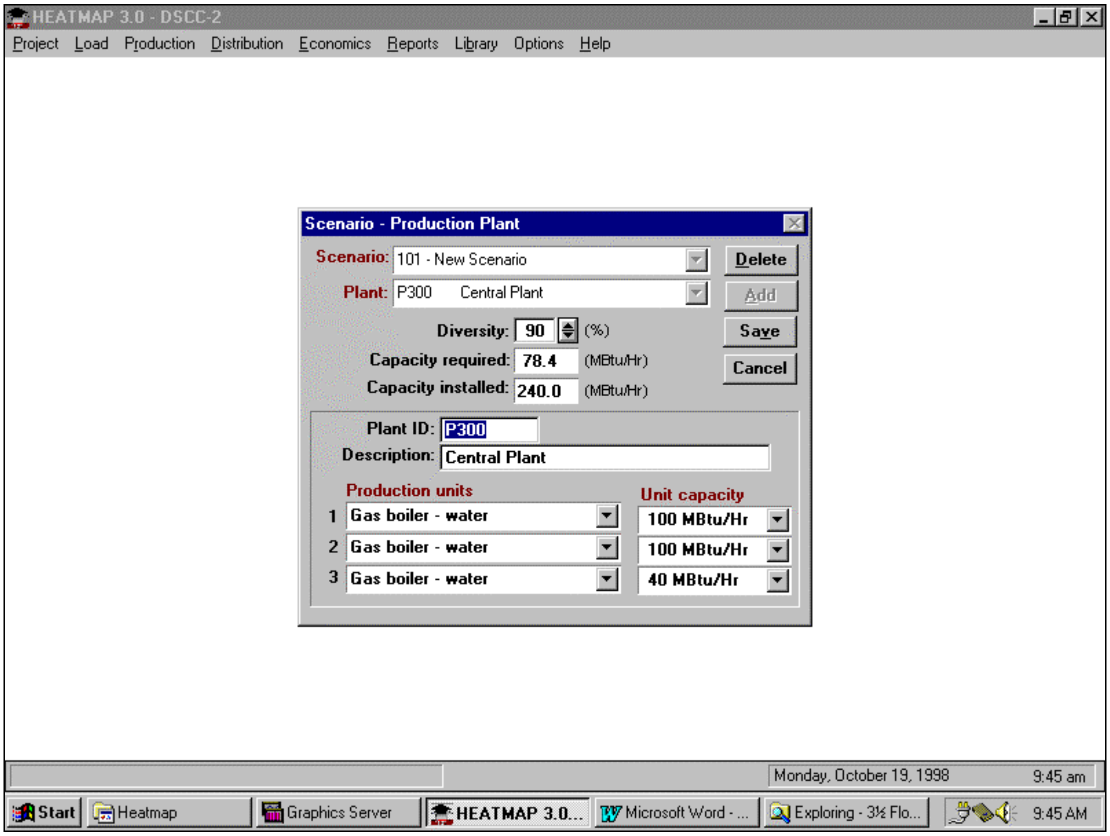


Figure 6. HEATMAP production plant interface.

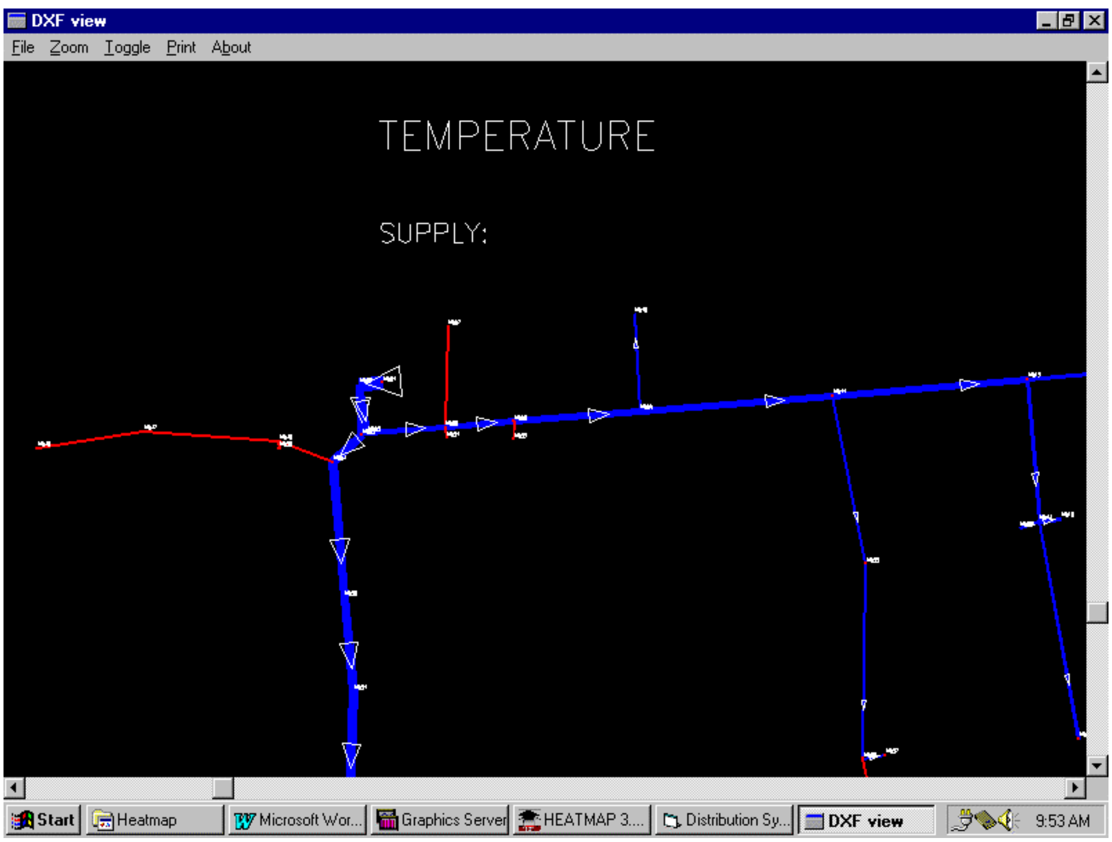


Figure 7. HEATMAP flow analysis.

HEATMAP uses the AutoLISP program in AutoCAD to take the graphical input to populate a Microsoft® Access database in HEATMAP. Once the data is input, AutoCAD is not necessary unless the pipe layout is changed. HEATMAP ports the building name over to the database and creates a record for the building with a default size of 5,000 sq ft. The user then selects a function from a pick list and modifies the building area information. If building load information is unknown, the user will request that HEATMAP calculate annual figures for heat peak load, energy use, domestic hot water load, and chill water load.

The results of the study (as shown in Figures 8 and 9) can then be used by base planners to map out an implementation plan to realize the most effective energy supply plan for the site.

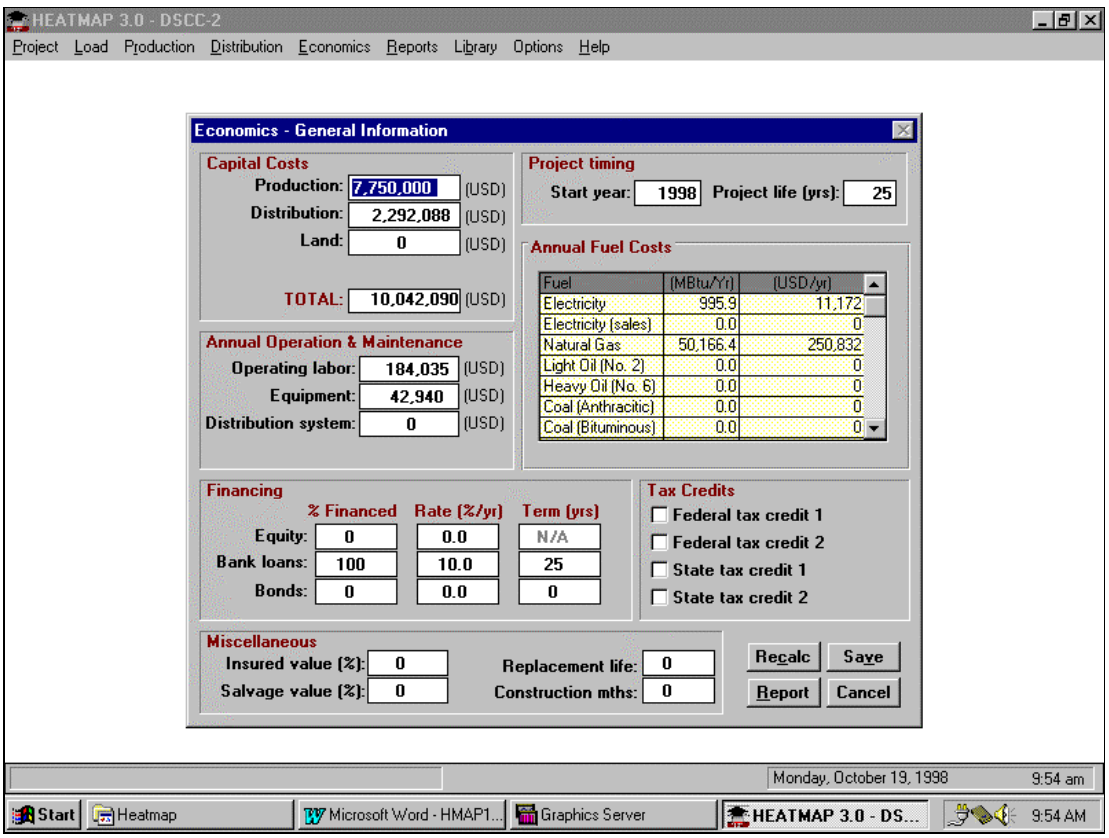


Figure 8. HEATMAP economic analysis output.

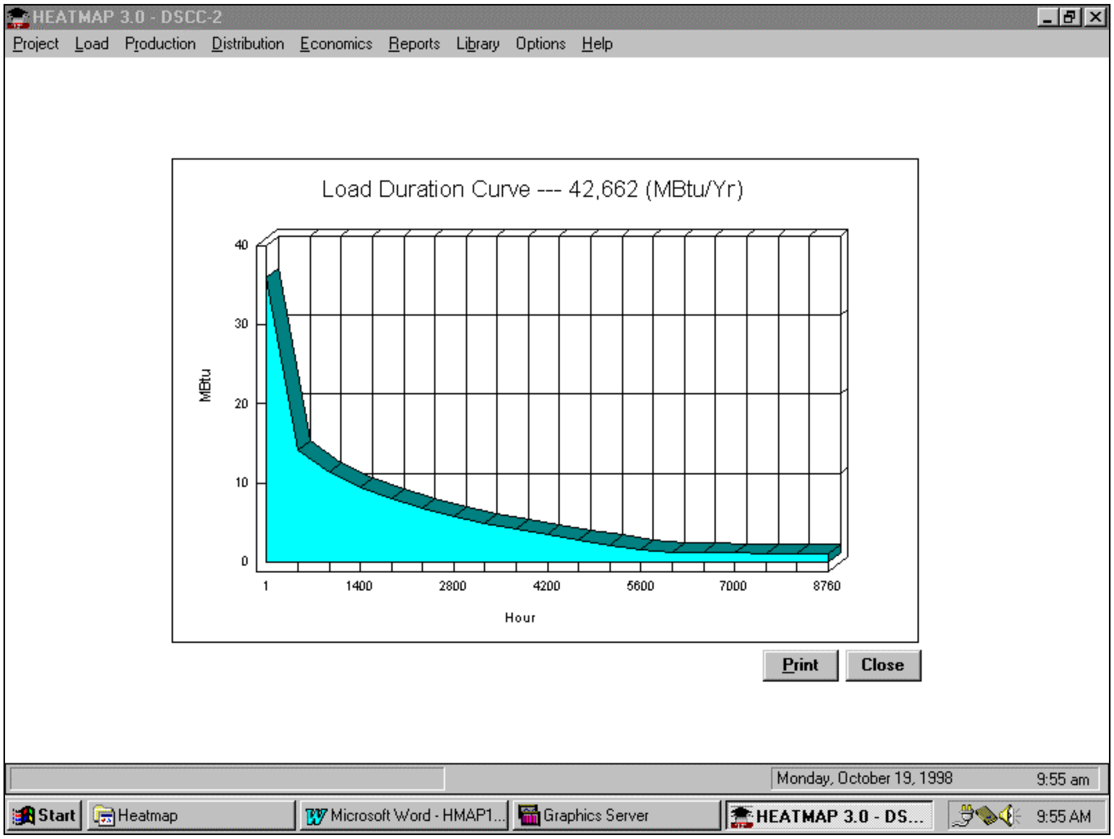


Figure 9. HEATMAP load duration curve output.

5 Heating Plant Modernization and Energy Supply Optimization

Introduction and Objectives

Modernization efforts for the Army's CHPs can be broadly described as programs that integrate the long range planning at the Department of the Army and MACOMs with the installation level programs for equipment condition assessment, refurbishment, monitoring, and improvement of O&M procedures. The life of a CHP is not limited by its nominal design life. Rather, it is limited by the cost of continuing to operate that CHP while meeting certain technical, economic, and environmental performance requirements compared to the cost of other available options (e.g., direct purchase of power or steam from other sources, construction of a new plant, or decentralization). Consideration of modernization includes technical and economic analyses and evaluations similar to those used when building a new CHP or decentralizing. As with new construction, plant performance (e.g., efficiency, availability) and cost factors (e.g., capital equipment, operation, and maintenance) must be integrated with the safety, environmental, regulatory, funding, DoD energy policy (e.g., privatization, financial risks, increased coal use), and fuel purchasing issues to make logical modernization decisions.

Currently, ACSIM is sponsoring a program to modernize about 30 heating systems. For these installations, it is vital to develop an energy supply strategy that reflects technological advances for meeting environmental standards, forecasts of availability of fuel, and expectations of new mission requirements.

Risks and Uncertainties

Economic analysis of typical industrial and utility projects indicate that modernization could result in cost savings or economic benefits (EPRI, March 1987; Council of Industrial Boiler Owners [CIBO], July 1989). However, any modernization program has inherent economic risks. For example, the longer the payback period or greater the life-cycle cost, the higher the risk that the failure of the refurbished equipment or other equipment may interfere with total cost recovery. Another risk for fossil fuel plants—particularly coal-fired plants—for which modernization is being considered, is uncertainty in regulations and permits.

Overview of the Central Heating Plant Modernization Program

The Army will be implementing CHP Modernization Projects (CHP MOD) at five to six enduring installations per year starting in FY98 and going through FY02. The Army will invest $60 million per year in the program ($300 million program total). The program is focusing on upgrading the thermal utilities to the most life-cycle cost-effective technology. CHPs and the associated distribution systems are being assessed and compared to other alternatives such as decentralized production, LTHW distribution, and hybrid energy plants. The advanced energy supply analysis process has been very valuable in developing and evaluating modernization plans. The appendix shows analyses for three of the installations.

Planned Modernization Projects (FY98-FY02)

Table 1 lists the projects in the planned modernization program. Some installations have more than one project. Final project approval and funding is contingent upon the installation's ability to execute an economically favorable project and obligate the funding on the project in one fiscal year.

Table 1. Planned modernization projects (FY98-FY02).

FY98	FY99	FY00	FY01	FY02	Unfunded
Meade	Riley	Carson	Redstone	Gordon	Picatinny
Jackson	Eustis	Aberdeen PG	Stewart	Rucker	Monmouth
Lewis	Campbell	Redstone	Gordon	Lee	Bragg
Aberdeen PG	Benning	Leonard Wood	Carson	Carlisle Barracks	Sill
Benning	Wainwright	Belvoir	McNair	Dix	Knox
Belvoir		Wainwright		Hood	Gillem
Drum				Myer	

Energy Supply Analysis Sites in CHP MOD

Fort Eustis

Background information.

The base operations at Fort Eustis are government operated. The cantonment areas encompass approximately 440 acres of land and 18.6 million sq ft of buildings.

All of the heating plants are relatively small and unmanned. A utility monitoring control system (UMCS) by Johnson Controls is being installed in the boiler plants. All of the systems are dual fueled by #2 oil and natural gas. High pressure (40-100 psig) and low pressure (< 15 psig) steam systems are used to provide heating and domestic hot water (DHW) to the buildings.

Heating plant survey.

In general, most of the plants and mechanical rooms were in fair to good condition. All of the plants will need some level of mechanical repair to realize the maximum benefit of improving the controls with a UMCS. Although the new METASYS™* UMCS system will greatly improve the centralized monitoring and control of the boiler plants, it is important that the mechanical pressure gauges, flow meters, and thermometers be maintained. These local indicators are valuable troubleshooting tools to a mechanic first entering an equipment room on a trouble call.

Fuel costs.

Current fuel costs at Fort Eustis are $0.53/gal ($3.87/MBtu) for #2 oil, and $3.60/MBtu for natural gas. However, those rates are annual averages. The gas rates at Fort Eustis vary widely over the course of the year. Also, there are cost differentials for those buildings on firm (uninterruptible) rates.

---

* METASYS is a trademarked product of Johnson Controls, Milwaukee, WI.

Energy screening.

The USACERL-developed energy screening tool described in Chapter 4 was used to develop cost curves for different heating systems based on previous DoD plant studies, Redbook* data, and utility bills from Fort Eustis. The aggregate energy density of the entire cantonment area is about 0.79 MBtu/hr/acre. However, the areas near the barracks may have energy densities that are much higher than the base average. The curves indicate central plants are favorable in areas where the density is above 0.6 MBtu/hr/acre (Figure 1). Decentralized systems are definitely more favorable in regions with energy densities below 0.3 MBtu/hr/acre. This preliminary screening indicates that central heating systems that are in good condition should be preserved.

Summary.

Aboveground steam piping is the safest, most reliable, and least expensive system to install and maintain. However, loss of condensate is a problem at Fort Eustis. Some of the condensate piping may need repair due to condensate grooving. Some of the underground sections may have failed as well. Corrosion of the condensate lines indicates that improvements may be needed to the water treatment program. A chemical analysis of the boiler water and the condensate should be performed to diagnose the cause of the problem and to determine the proper remedy. If most of the buildings convert steam to LTHW for space heating, the steam pipe sizing should be checked for conversion to LTHW distribution if the condensate systems have completely failed.

Fort Riley

Background.

The base operations at Fort Riley are government operated. The cantonment areas encompass approximately 3,000 acres of land and 18.6 million sq ft of buildings.

Due to the heating plant modernization program and the barracks upgrade program (BUP), Fort Riley was particularly interested in assessing the alternatives in the 8000 area of Custer Hill. This area comprises 30 buildings including 12

---

* Redbook = Department of the Army Directorates of Public Works Annual Summary of Operations.

barracks, company headquarters, battalion headquarters, a mess hall, gymnasium, detached day rooms, and training centers. Total building area is more than 400,000 sq ft over an area of about 22 acres. With a peak combined building load of 13.2 MBtu/hr, the 8000 area has a peak energy density of 0.6 MBtu/hr/acre. The facilities were constructed in the mid-1970s. Part of the BUP, design of the barracks is nearing completion and the first two barracks are scheduled for renovation in FY99.

All heating and cooling in the area is provided by a central plant in Bldg 8073. The plant houses two high-pressure steam, natural gas-fired boilers at 16 MBtu/hr (500 hp) each, and two single-effect steam absorption chillers at 440 tons each. This equipment is original and nearing the end of its useful life. Maintenance of the high-pressure steam requires significant manpower.

High-pressure steam is distributed to the buildings year round for DHW production in the barracks, mess hall, and gymnasium. Winter heating is provided by steam to hot water converters located in all buildings. Approximately half of the 8,000 linear feet of steam distribution system piping is in shallow trenches and the remainder is direct buried. The shallow trench portion was constructed in 1990. The remaining direct buried portion is original and in poor condition. During the summer, chilled water is distributed to all buildings. The chilled water distribution system is direct buried and in good condition.

The central heating/cooling system is in need of replacement. Eight heating and cooling supply options were studied by USACERL in 1996 (Dilks 1996). Fort Riley revisited the study in 1998 and developed five alternatives in lieu of a direct replacement of the existing system (Imel 1998). All of the revised options call for replacing the absorption chillers with high efficiency electric units. The existing chilled water distribution system will remain in use. The heating portions of the options are briefly summarized below.

Option A—This option changes the existing steam system to LTHW. All boilers would be housed in the existing plant (Bldg 8073). Existing steam distribution lines in shallow trench would be reused when the size was sufficient. The direct buried portion of the system would be replaced with shallow trench. LTHW would be provided year round and used by instantaneous hot water heaters in the barracks, mess hall, and gymnasium. Other buildings would either have no DHW or use small gas or electric units. The LTHW system would provide heat in the winter.

Option B—This option is identical to Option A except that it runs gas lines to the buildings using instantaneous DHW heaters. By replacing the instantaneous heaters with gas, the boiler and distribution sizes could be significantly reduced. The LTHW system would only operate during the heating season as DHW is produced by individual gas heaters.

Option C—This option splits the heat distribution system into two loops. An additional plant building would be constructed in the middle of the 8000 area. By splitting the system, the existing steam lines in shallow trench would have sufficient size to be used for LTHW. The existing direct buried lines, along with any new lines, would be placed in a shallow trench. The LTHW systems would operate year round to provide DHW.

Option D—This option eliminates the central heating system. Natural gas lines would be installed to all buildings. Each building would have its own boiler or furnace for heating. Buildings requiring DHW would have a gas heater. The existing mechanical rooms in the barracks are not large enough for this equipment. However, the BUP design calls for the expansion of the mechanical room into an existing sleeping room. This requires moving a non-load-bearing wall and maintaining the required fire rating. The cost estimate for Option D includes the cost of the mechanical room expansion in the event the Utility Modernization Program (UMP) project precedes the BUP renovations.

Option E—This option is identical to Option A, except that storage-type DHW systems are used in the barracks, mess hall, and gymnasium. By replacing the existing instantaneous DHW heaters, the boiler and distribution line sizes can be greatly reduced. The LTHW system would only operate during the heating season.

Table 2 summarizes the non-energy costs related to each option. The construction cost estimates were developed by the A&E under contract to provide design services. The costs do not include 6 percent SIOH* and 6 percent contingency funds. Maintenance costs were developed after consultations with the O&M Division.

Option D has a lower life-cycle cost than the other options due to the much lower construction costs. Fort Riley is proceeding with the design of Option D.

---

* SIOH = supervision, inspection, and overhead.

Table 2. Fort Riley non-energy-related project costs.

Option	Construction Heating System	Construction Cooling System	Construction Total	Annual Maintenance
A	$4,380,124	$ 829,875	$5,209,999	$98,000/yr
B	$3,833,138	$829,875	$4,663,013	$120,000/yr
C	$3,816,056	$829,875	$4,645,931	$110,000/yr
D	$2,129,323	$829,875	$2,959,198	$133,000/yr
E	$3,175,956	$829,875	$4,005,831	$ 98,000/yr

Project status.

The FY99 Utilities Modernization Program Support Team visited Fort Riley 1-2 September 1998. The team had the opportunity to review design submittals for the BUP as well as the heating plant modernization plans.

Fort Riley is planning on implementing a decentralized LTHW heating system in the 8000 barracks area using an instantaneous gas system for DHW. The uninterruptible natural gas will be provided to all the buildings.

All the barracks will have expansion of their boiler rooms. The BUP contractor can only work two barracks at a time throughout the course of the BUP.

Fort Carson

Background information.

The base operations at Fort Carson have been contractor operated for almost 10 years. The central cooling plants, CHPs, distribution systems, and building HVAC systems are all operated and maintained by Pacific Architects and Engineers Incorporated (PAE). In FY96 PAE charged Fort Carson $68,000 for chiller operations, $64,000 for chiller maintenance, $531,000 for heat system maintenance, and $389,000 for heat system operation. The cooling season runs from 15 June to 15 September and the heating season runs from 15 October to 15 May. The cantonment area encompasses approximately 2,500 acres of land and 12.4 million sq ft of buildings.

High temperature hot water (HTHW) and steam are used to deliver heating and DHW to the buildings. Four plants serve most of the buildings; one HTHW plant (Bldg 1860), one HTHW/steam plant (Bldg 6290), and two steam plants (Bldgs

9609 and 403). All of the plants except Building 403 are gas- and oil-fired. Building 403 is gas-fired only.

In general, most of the plants and mechanical rooms were in good condition. The main central chiller plant at Building 1864, however, was in urgent need of repair for the 1998 cooling season. Fort Carson was in the process of retubing one of the chillers to meet the season's cooling needs.

Fuel costs.

Current fuel costs at Fort Carson are $0.70/gal ($5.18/MBtu) for #2 oil, $0.99/gal ($10.42/MBtu) for propane, and $2.57/MBtu for natural gas. Fort Carson and the U.S. Air Force Academy have combined their fuel needs to negotiate good interruptible and firm gas rates from the City of Colorado Springs.

Data analysis.

The USACERL-developed energy screening tool discussed in Chapter 4 was used to develop cost curves for different heating systems based on previous DoD plant studies, Redbook data, and utility bills from Fort Carson. Although the energy density of the entire cantonment area is about 0.31 MBtu/hr/acre, there are areas near the barracks where the density is much higher. The curves indicate central plants are favorable in areas where the density is above 0.65 MBtu/hr/acre. Decentralized systems are definitely more favorable in regions with energy densities below 0.3 MBtu/hr/acre. This preliminary screening indicates that central heating systems that are in good condition should be preserved. Fort Carson's actual cost curves for the central plants may be lower as the cost billed by the contractor to operate and maintain the heating systems was $1.53/MBtu delivered to the building as compared to the Army average of $3.86/MBtu delivered to the building. This cost is at the lower end of the non-fuel O&M costs reported by industry and institutional steam plants.

Summary and recommendations.

No serious problems have been observed at the heat plants at Fort Carson. The HTHW system off of Building 1860 is a main and lateral system. Some valve repairs may be needed. It is difficult to manage outages in some sections due to the valve condition and piping configuration. However, PAE reports that underground sections that have been unearthed appear to be in good condition. Work on the HTHW system would probably focus on repairs and modifications to make the system more reliable and flexible. If the system had two mains or a loop, major sections could be isolated, depressurized, and cooled down to allow repairs.

Fort Carson is in the initial stages of establishing an energy savings performance contract (ESPC). The installation is concerned that CHP repairs may interfere with the bundling of energy conservation opportunities (ECOs) in the ESPC contractor's proposal. The importance of obtaining an accurate baseline measurement of the current cost of operation cannot be overemphasized. If the baseline is overestimated, the installation risks "overpaying" for saving. If the baseline is underestimated, the contractor may not be able to find enough ECOs to get a fair return on its investment. USACERL can provide technical assistance with screening for ECOs and estimating the baseline costs.

Other CHP MOD sites

Fort Drum

Background.

The proposed project originally consisted of replacing an existing direct buried HTHW distribution system that was in poor condition. The proposed replacement design was a shallow concrete trench system with occasional short runs of aboveground piping. However, in 1997 Fort Drum elected to proceed with a decentralized system once the cost of replacing extensive portions of the HTHW lines became prohibitively expensive.

The existing direct-buried HTHW piping system at Fort Drum was installed in 1987. The system has failed prematurely due to leaks in both the conduit and the carrier pipe. Failures in the conduit were evidenced by its inability to hold pressure. Failures in the carrier pipe were evidenced by the leakage of treated HTHW into the annulus (area between the carrier pipe and conduit).

USACERL was asked to investigate the problem and to predict the remaining life of the existing direct-buried carrier and conduit pipes. Chemical analysis of the piping samples and water samples were taken to quantify the current condition. Then using a tool called SCALER, USACERL calculated the remaining life of the pipes. SCALER was developed by USACERL and FORSCOM in the late 1980s to predict the effects of corrosion on water piping based on physical information about the piping system and the chemistry of the water conveyed. Water chemistry and pipe data were entered into SCALER and prediction reports were generated.

Results.

Based on SCALER predictive models for pitting corrosion of galvanized steel at elevated temperatures, the carrier pipe (2 in. diameter x 0.218 in. wall thickness) could fail by pitting corrosion in less than 5 years. This prediction is upheld by the fact that Fort Drum has pressure tested the annulus between the carrier and conduit and could not maintain the required 15 psi for 1 hr. In addition, treated HTHW was detected in one of the water samples from the annulus at manhole 19. Since the groundwater is only slightly corrosive to steel, the most likely scenario for failure would be the following series of events:

- Groundwater enters the annulus between the conduit and carrier pipes. There are at least three likely causes of the groundwater intrusion. The most likely cause is seepage through the drain or vent in the end cap at the manhole. Another possible cause is conduit penetration due to soil-side pitting corrosion. Soil-side pitting corrosion is less likely than seepage through the drain or vent (due to the longer time required). Also, previous work done at Fort Drum has indicated that the soil is not very corrosive. However, Fort Drum personnel have reported that failure of the conduit did occur at the conduit/manhole junction due to galvanic and/or concentration cell corrosion. The third possible cause of groundwater intrusion is defective weld joints. DPW personnel reported that they had observed water intrusion into the annulus due to a lack of complete weld joints in the conduit at the expansion loops.

- The heated groundwater (minimum 162 °F) is chemically altered and becomes soft and very aggressive or corrosive to steel.

- The boiling groundwater causes severe pitting corrosion on the interior surface of the conduit. This allows more groundwater to intrude. Physical examination of interior surfaces of the conduit did not reveal any significant difference in the amount of corrosion (i.e., there was uniform pitting around the circumference of the conduit).

- Eventually (in less than 5 years) the very corrosive boiling groundwater in the annulus causes failure of the exterior surface of the carrier pipe by pitting corrosion.

- This failure allows treated HTHW to enter the annulus and mix with the groundwater, rendering it less corrosive.

- Eventually the entire system fails (in as little as 5 years) and requires total replacement.

Examination of the interior surface of the carrier pipe revealed little or no visible corrosion occurring. This lack of corrosion indicates an excellent water treatment program is being used at the CHP.

It is interesting to note that the application of cathodic protection would probably not have prevented the failure of either the conduit or carrier pipes since there was extensive groundwater intrusion from the lack of welds or missing drain and vent plugs. This conclusion can be made because the pitting corrosion was initiated on the inside of the annulus. If the conduit failed due to soil-side corrosion or galvanic corrosion at the conduit/manhole junction, then cathodic protection would be an effective corrosion prevention measure.

Summary.

Based on the water chemistry, pipe examination, and SCALER prediction models, the following conclusions can be made concerning the direct-buried HTHW piping system at Fort Drum:

- The remaining life of the piping system could be as little as 5 years due to the failure of the carrier pipe as a result of pitting corrosion.

- The primary failure mode of the conduit appears to be pitting corrosion induced by corrosive boiling water. The groundwater intrusion most likely occurred at the manhole or expansion loops.

- The primary failure mode of the carrier appears to be pitting corrosion of the exterior surface due to exposure of boiling groundwater. The very slightly corrosive groundwater is chemically altered by boiling with the insulated materials over long periods of time (greater than 90 days).

- The conduit pipe will not pass a pressure test (15 psi for 1 hr). This indicates penetration, which allows continual intrusion of groundwater.

- There is evidence of at least one failure of the carrier pipe near manhole 19. The water analyses revealed the presence of treated HTHW in the pipe annulus.

Fort Campbell

Background.

Fort Campbell has submitted a utilities modernization project for funding in FY98 as part of the Army's UMP.

USACERL was tasked to conduct a preliminary HEATMAP analysis of the steam distribution system at Fort Campbell to calculate accurate construction and fuel consumption estimates. Three new scenarios were modeled, all of which included shallow trench piping and one new low-NOx boiler or hot water generator from another project. These scenarios included:

- A new steam system using the existing boilers
- A new LTHW system using the existing boilers and cascade heaters
- A new LTHW system using three new hot water generators, two at 35 MBtu/hr and one at 15 MBtu/hr.

It was assumed that natural gas was the only fuel used for the new scenarios. It is recommended that dual fuel capabilities, either #2 oil or a propane/air mix, should be maintained to support an interruptible gas rate and to provide greater system reliability.

A HEATMAP analysis was conducted on the existing system. An electronic map of the distribution system was provided as well as building loads, boiler logs, and O&M costs from a previous study completed by Systems Engineering Management Corporation (Systems Corp). All of these data were used to validate the HEATMAP model for the existing system. This information was then used to estimate distribution system costs and annual fuel consumption for new steam and LTHW systems using shallow trench piping systems. Estimates for boiler retrofit costs were taken from 1997 R.S. Means data and did not include costs for the installation of a new low-NOx boiler from another project. Demolition cost estimates were obtained from a project at Fort Dix, NJ, where they were removing similar size boilers from an existing plant.

The installation of the current heating system was completed in 1977. Boiler Plant 3902 consists of two 50 MBtu/hr #2 oil/gas-fired boilers and one 15 MBtu/hr #2 oil/gas-fired boiler. All the boilers are of water-tube design and were manufactured by Nebraska Boiler. The working steam pressure is 92 psig. A previous study completed by Schmidt Associates, Inc. (SAI) revealed that the existing boilers were in good condition and operating near the design efficiency of 80 percent. At least an additional 20 years of boiler life is expected. However, the direct-buried steam supply and condensate return systems are in poor condition and are resulting in high energy losses. This system currently serves two barracks complexes and the Lee Family Housing Area. The family housing area will not be included in this study since an alternate means of heating and cooling will be installed there.

Steam is used primarily for heating and DHW production. Buildings 3603 and 4061 require steam for humidification and kitchen equipment. Of the 54 buildings on the system, 19 use steam directly in their heating system, with the rest converting to LTHW in the mechanical room before distribution inside the building. Retrofit costs of $1,300,000 for conversion of the 19 buildings from steam to LTHW were pulled from the Systems Corp study. From the boiler logs, the average hourly steam flow was plotted against the average daily temperature. The minimum load averaged just above 12,000 lb/hr for average daily temperatures above 65 °F. The average base load, which included DHW and process loads, was calculated to be 2,000 lb/hr, indicating an average loss of 10,000 lb/hr in the distribution system. The maximum load of 78,000 lb/hr occurred on a day with an average temperature of 5 °F. The design day for Nashville, TN, is 14 °F. At 14 °F the boiler log sheets show an average flow of just over 60,000 lb/hr. Figure 10 shows the steam load versus outdoor temperature relationship.

Steam flow and fuel consumption are the most reliable energy use data available from the logs at Fort Campbell. USACERL used the steam flow data to validate the HEATMAP flow model for the design day and the thermal loss estimate.

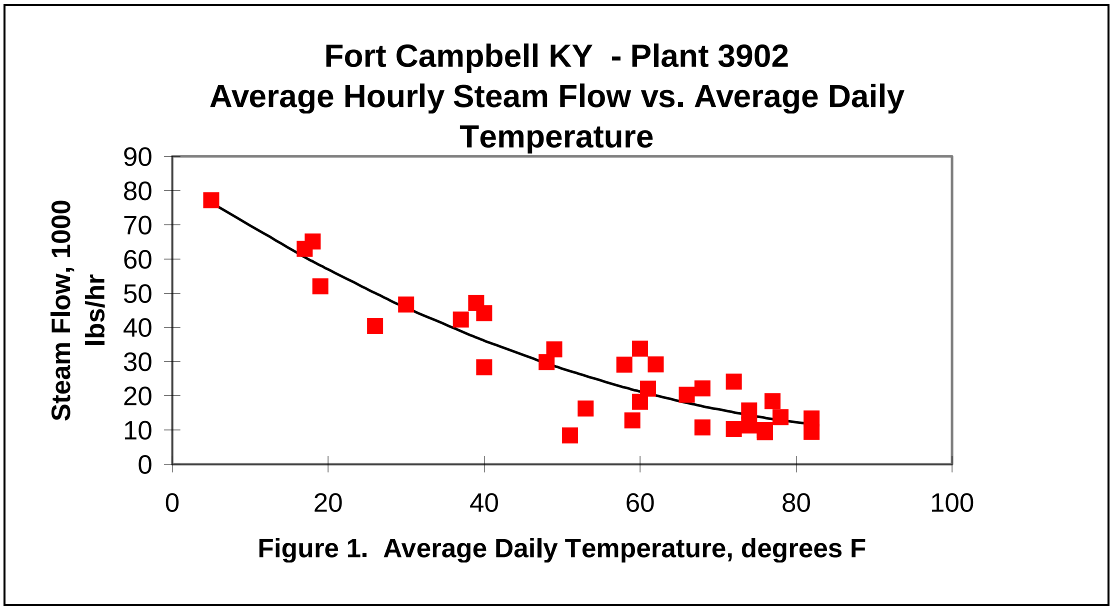


Figure 10. Steam flow versus daily temperature, Fort Campbell, KY.

Both the thermal loss estimate and the annual fuel consumption were used to estimate the annual building thermal load. The plot of the steam flow shown below identifies large thermal losses of nearly 8,500 lb/hr or 10 MBtu/hr. The SAI study also indicated that the boiler combustion efficiency was about 80 percent. The 10 MBtu/hr loss equates to an annual consumption of 110,000 MBtu of natural gas. Annual fuel consumption was reported to be 231,000 MBtu. This leaves nearly 121,000 MBtu of natural gas to provide for the actual heating load. At 80 percent efficiency, the annual heating load was estimated to be approximately 97,000 MBtu.

The slope of the data shows a peak building heating load is about 65,000 lb/hr for a 5 °F day. At 14 °F (the design day), the heating load is around 50,000 lb/hr. An additional 2,500 lb/hr are added to the estimated peak heating load to account for the process load and the peak DHW load. The total peak consumer load for the base is estimated to be 52.5 lb/hr, which is assuming a condensate return temperature of 190 °F. An additional 10 MBtu/hr of distribution system losses would result in a peak plant output of 62.5 MBtu/hr.

Fuel costs.

Current fuel costs at Fort Campbell are $0.60/gal for #2 oil and $3.31/MBtu for natural gas. The previous study (prepared by Systems Corp) used a natural gas price of $4.71/MBtu. The new scenarios consumed only natural gas as a fuel. Economic analyses were completed for both of the natural gas prices that were quoted in the earlier study.

Summary.

A new shallow trench LTHW distribution system using a loop around each barracks complex would provide the lowest annual O&M costs and the lowest annual fuel consumption. The shallow trench LTHW distribution system will cost approximately $6.5 million. The piping cost estimates used were for a HTHW system and are most likely high enough to include the design and contingency costs for an LTHW system. Therefore, a contingency is already built in to the estimate for the distribution system. Table 5 compares the life-cycle costs.

Table 3. Fort Campbell life-cycle cost summary.

(All PW values are in 1000s of 1997 $)	**Existing Steam**	**New Steam**	**LTHW Cascade**	**LTHW New Boilers**
Capital Cost PW	0	5,650	7,539	8,392
O&M PW	8,657	2,587	2,424	1,286
Salvage Value PW		-982	-1,308	-1,308
Fuel PW @ $3.31/MBtu	13,741	9,243	8,446	8,242
Net PW @ $3.31/MBtu	22,398	16,498	17,101	16,612
SIR @ $3.31/MBtu	-	2.3	1.9	1.8
DPP @ $3.31/MBtu	-	9	11	11
Fuel PW @ $4.71/MBtu	19,553	13,152	12,018	11,728
Net PW @ $4.71/MBtu	28,210	20,407	20,673	20,098
SIR @ $4.71/MBtu	-	2.7	2.2	2.1
DPP @ $4.71/MBtu	-	8	9	9

Even though the new steam has the highest SIR and lowest DPP, it has a higher cost risk as, without proper maintenance, it could quickly deteriorate to a condition that would consume up to 25 percent more fuel annually, primarily due to condensate return line and steam trap failure. Also, the total life-cycle costs are so close (about 1 percent difference) they can be considered equivalent. LTHW systems are at a technical advantage because they do not produce corrosive condensate and do not use steam traps; thus, they are more likely to provide thermal energy efficiently throughout the economic life of the system.

6 Future Energy Supply Issues

Several technologies and issues will need to be considered when managing energy supplies in the next 2 to 10 years.

Low NOx Limits

Recent regulation by the U.S. Environmental Protection Agency (EPA) has reduced the nitrous oxide limits for utility and industrial steam generating units for all fuels to that of natural gas and distillate oil (EPA, September 1998). The old Subpart Db limits (EPA, October 1998) were fuel specific as listed in Table 4.

Table 4. Federal nitrogen oxide limits for subpart Db steam generating units.

Fuel/Use	Lb/MBtu/hr Input
Gas and oil (low heat release rate)	0.10
Gas and oil (high heat release rate	0.20
Residual oil (low heat release rate)	0.30
Residual oil (high heat release rate)	0.40
Coal Spreader Stoker	0.60

The new limits will be 0.20 lb/MBtu for all fuels for industrial units classified as Subpart Db units (100 to 250 MBtu/hr heat input). The low heat release rate limit for gas and distillate oil of 0.10 lb/MBtu will not be changed.

Micro-Cogeneration

Advances in air and foil bearings and natural gas compressors are enabling commercialization of microturbine generators. Several companies will be marketing units in the 17 to 100 kW range that will cost $450 to $700/kW installed (Zuckerman 1997). Since the turbine generator is direct drive with an air-foil bearing, reduction gear and lubricant maintenance is eliminated. Additionally, many of the units will have heat recovery options. One of the challenges of cogeneration is the transport and management of the recovered heat. Many times the heat recovery user is not located at the generation plant. The heat needs to be converted to steam or hot water and transported to the user. With smaller micro-cogeneration units, the electrical production and heat recovery can be moved closer to the end user reducing transportation and storage losses.

Fuel Cell Cogeneration

USACERL has successfully demonstrated the technical feasibility of phosphoric acid fuel cells at 30 DoD sites. Although the installed cost is still high at $3,000/kW, these units have such low emissions that they are exempt from air quality permitting. Additionally, these units provide hot water for heating or processes for the user.

Photovoltaics

USACERL has successfully demonstrated photovoltaic (PV) energy supply at several DoD sites that have high electric rates, or power needs where installing utility lines would not be economical. Typically, the electric loads being served are relatively small, less than 5 kW. The sites are either far from the local utility grid or in an area where extending the grid, even a short distance, would require additional equipment and/or construction costs. These additional costs eliminate grid extension as a viable alternative. Other conventional power supplies considered for these applications include small engine-driven generators and batteries, but the life-cycle cost for these alternatives is very high. Surveys conducted by various DoD agencies have shown that there are literally tens of thousands of existing sites that fit this profile for telecommunications, lighting, or other field equipment loads. Additionally, a facility may have sites where conventional electric service has been ruled out in the past, but should be reconsidered with a PV system as the power supply. The features that make PV power an attractive option include:

- ***Reliable, standalone power supply***—Properly designed PV systems can survive some of the harshest operating conditions and reliably provide power, unattended, for long periods of time. They have no moving parts, so maintenance and replacement of system components is greatly reduced. A reliable power supply increases the reliability and state of preparedness of the equipment being served, such as a vehicle starting battery or a weather data collection platform.

- ***No fuel requirements***—Using a PV power system instead of, or in combination with, an engine-driven generator reduces the use of mobility fuels. Fuel transportation costs are also reduced. In cases where fuel is delivered by helicopter, or over great distances by boat or truck, the transportation cost is sometimes higher than the cost of the fuel itself.

- ***Modularity***—Because the PV system can be sized to closely match the load, both for power and energy, system efficiencies are maximized. If the load changes at a particular site, the PV system can be reconfigured fairly easily to meet the new requirements. Engine-driven generators come in specific sizes and are typically oversized. An underloaded generator has poor fuel efficiency and requires more frequent maintenance.

- ***Environmental benefits***—PV systems produce no harmful pollution and meet some of the strictest requirements of the EPA and the National Park Service. The environmental risks of fuel handling and storage are also minimized. For military combat considerations, PV systems emit no noise or detectable thermal signature. Used in combination with fossil fuel generators, hybrid PV systems increase the efficiency of the generators and, in turn, help reduce emissions from the conventional equipment. When used to charge batteries at off-grid sites, PV systems extend the useful life of the batteries by maintaining a higher state of charge and reducing hazardous O&M handling procedures (Ducey 1998).

7 Summary

This research examined issues involved in energy supply optimization and developed generic guidelines for analyzing energy supply strategies. These guidelines are based on research from a variety of sources and are intentionally broad.

Energy supply modernization programs are affected by economic and regulatory forces and by the type and amount of fuel the installation uses. Modernization programs include certain risks. Therefore, the installation must develop an energy supply strategy that best suits its needs.

In general, many Army sites do not have the energy supply density to justify building new, large district heating and cooling systems. Some sites will have buildings clustered close enough to use a CHP. However, central systems lend themselves well to cogeneration to improve cycle efficiency. This practice reduces the amount of fuel consumed to produce a desired effect. Central systems are also able to switch fuels to reduce reliance on one fuel supplier.

Decentralized boilers and heaters are better suited to sparse geography. Additionally, decentralized boilers can be contracted out with the building operation. The Army can package the building operation, repair, and heating into one scope of work for a facility operations company. However, these small boilers and hot water heaters will still require a fixed amount of maintenance regardless of the boiler size. Also, these units are usually fired by gas only. The price for firm (uninterruptible) gas can be 30 to 40 percent more expensive than for interruptible gas.

Strategies should be specifically tailored to the installation to help meet long-range installation planning. The overall goal of an energy supply strategy should be procure, convert, and transport energy to the end user in the most effective and reliable method suitable to the economic and environmental conditions at the installation.

References

Cited

Army Regulation (AR) 420-49, *Heating, Energy Selection and Fuel Storage, Distribution, and Dispensing Systems* (Headquarters, Department of the Army [HQDA], 22 June 1990).

Bloomquist, R. Gordon, J.D. Nimmons, and Kevin Rafferty, *District Heating Development Guide, Legal, Institutional and Marketing Issues*, Volume 1 (Washington State Energy Office, Olympia, Washington, June 1987).

Council of Industrial Boiler Owners (CIBO), *Proceedings of Boiler Life Extension II* (CIBO, July 1989).

Defense Energy Program Policy Memorandum (DEPPM) 91-2, *Implementing Defense Energy Management Goals*.

Defense Reform Initiative (DRI), November 1997 (http://www.defenselink.mil/dodreform/index.html, viewed September 1998).

Dean, J.D., *A Case Study of Steam Generation Replacement at DuPont's Louisville Plant* (Stoker Efficiency Network Workshop, August 1998).

Dilks, Chris, *Feasibility Study of District Heating and Cooling System Operations for the Custer Hill Area at Fort Riley, Kansas,* U.S. Army Construction Engineering Research Laboratories (USACERL) Summary Report (September 1996).

Ducey, Roch, *Technical Instructions for Photovoltaic Power Systems (Draft),* (http://www.hnd.usace.army.mil/techinfo/ei.htm), December 1998.

Electric Power Research Institute (EPRI), *Strategies for Fossil Plant Life Extension*, Report No. CS-4781 (EPRI, March 1987).

Energy Information Agency (EIA) Web Site (http://www.eia.doe.gov/price.html, viewed September, 1998).

U.S. Environmental Protection Agency (EPA), Revision of Standards of Performance of Nitrogen Oxide Emissions From New Fossil-Fuel-Fired Steam Generating Units, *Federal Register,* September 16, 1998, pp 49442-49455 (http://www.epa.gov/fedrgstr/EPA-AIR/1998/September/Day-16/a24733.htm.

EPA, Subpart Db, 40 CFR Part 60, (http://www.epa.gov/docs/epacfr40/chapt-I.info/subch-C/40P0060/40P060Db.pdf, viewed October 1998).

Imel, Mark, *Utilities Modernization Program Summary Memorandum*, September 1998.

Perkins, R.P., "DuPont's Life Extension History," *First Annual Boiler Life Extension Seminar* (Council of Industrial Boiler Owners [CIBO], 1986), p 121.

Public Law (PL) 102-486, *The Energy Policy Act of 1992*, Subtitle F, Federal Agency Energy Management.

Technical Manual (TM) 5-650, *Repairs and Utilities: Central Boiler Plants* (HQDA, 13 October 1989).

Zuckerman, Laurence, "Tiny Turbine: the Next Generator?" (*The New York Times*, Business Day, December 2, 1997).

Uncited

Chapman, Richard, Photovoltaics in the Department of Defense, Sandia National Laboratories (http://www.sandia.gov/pv/hot/Pvq_197.htm#anchor520921), viewed October 1998.

CIBO, *First Annual Boiler Life Extension Seminar*, 1986.

CIBO, *Industrial Power Plant Improvement (IPPI) Technical Conference* (CIBO, May 1991).

EPRI, *Generic Guidelines for the Life Extension of Fossil Fuel Power Plants*, Report No. CS-4778 (EPRI, November 1986).

EPRI, *Strategy for Fossil Plant Life Extension at Niagara Mohawk's Huntley - 67*, Report No. CS-4780 (EPRI, January 1988), pp 1-21.

HEATMAP Version 1.0 - A Computerized Tool for Analyzing District Heating and Cooling System Feasibility, Washington State Energy Office, WSEO #91-372 (WSEO, June 1992).

Lawrie, L.K., et al., Life Cycle Cost In Design (LCCID) Economic Analysis Computer Program User's Manual, BLAST Support Office, Department of Mechanical and Industrial Engineering, University of Illinois, 1988.

LiHach, N., “Extending the Lifespan of Fossil Plants,” *EPRI Journal*, June 1983, pp 7-15.

Magee, D.R., “Boiler Condition and Useful Life Study,” *First Annual Boiler Life Extension Seminar* (CIBO, 1986), p 191.

Savoie, M.J., and R.J. Miller, “Evaluation of Boiler Tuneup vs Replacement,” Draft Report (USACERL, 1989).

Savoie, M.J., et al., *Energy Supply Alternatives for Picatinny Arsenal, NJ*, Technical Report FE-92/04/ADA256863 (USACERL, 1992).

Training and Doctrine Command (TRADOC), *Strategic Utility Planning Program*, Volumes 1 and 2 (Headquarters, TRADOC, December 1993).

U.S. Air Force Central Heating Plant Tuneup Workshop, Special Report E-90/03 (USACERL, 1990) (16 volumes):

Savoie, M.J., G. Maples, and D.F. Dyer, *Volume I: Introduction*, ADB142803.

Maples, G., D.F. Dyer, M.J. Savoie, and R.E. Moshage, *Volume II: Description of Boilers*, ADB142129.

Maples, G., D.F. Dyer, and M.J. Savoie, *Volume III: Description of Burners*, ADB143333.

Maples, G., D.F. Dyer, and M.J. Savoie, *Volume IV: Fuel Oil Quality*, ADB141113.

Biederman, R., C.F. Blazek, S. McCammon, R.E. Moshage, and M.J. Savoie, *Volume V: Coal Quality*, ADB142914.

Standerfer, J.F., and M.J. Savoie, *Volume VI: Coal Handling and Storage*, ADB143136.

Schmidt, C.M., J.E. Davidson, S. McCammon, R.E. Moshage, and M.J. Savoie, *Volume VII: Coal Combustion Equipment*, ADB141114.

Maples, G., D.F. Dyer, and M.J. Savoie, *Volume VIII: Combustion Control — Oil and Gas*, ADB141115.

Maples, G., D.F. Dyer, and M.J. Savoie, *Volume IX: Combustion Control — Coal*, ADB143011.

Maples, G., D.F. Dyer, J.F. Standerfer, and M.J. Savoie, *Volume X: Steam and Condensate Systems*, ADB141454.

Maples, G., D.F. Dyer, and M.J. Savoie, *Volume XI: Efficiency*, ADB141661.

Maples, G., D.F. Dyer, and M.J. Savoie, *Volume XII: Water Quality*, ADB141116.

Maples, G., D.F. Dyer, and M.J. Savoie, *Volume XIII: Operation and Maintenance*, ADB141117.

Maples, G., D.F. Dyer, and M.J. Savoie, *Volume XIV: Economics*, ADB141373.

Standerfer, J.F., and M.J. Savoie, *Volume XV: Ash Handling*, ADB143291.

Richards, J., and M.J. Savoie, *Volume XVI: Air Pollution Control Systems*, ADB142292.

Appendix: Advanced Energy Supply Analyses

Fort Carson Screening

Advance Energy Screening Analysis — Site General Data

Notice to users:
This sheet is to assist a base or command engineer screen for the economic viability of several energy supply options. To select the most life-cycle cost effective option, a more detailed analysis will need to be conducted. Contact the Utilities Division, USACERL, Champaign, IL 61826-9005 (800)872-2375 ext 5505 or Mechanical and Energy Division, U.S. Army Center for Public Work, Ft Belvoir, VA (703) 806-6067

Front Sheet

Site Name: Ft Carson

	Name	Phone
POC's:		
MACOM POC		

Energy Supply — Ft Carson

Energy Supply Information
Utility Prices

Natural Gas Utility Rates:

			$/MBTU				
Summer Rate	$0.40	$/therm	$4.01	from		through	
Winter Rate	$0.40	$/therm	$4.01	from		through	

Electric Utility Rates:

			$/MBTU				
Summer Dem.	$8.00	$/kW		from		through	
Ratchet		%		from	Jan	through	Dec
Winter Dem.	$8.00	$/kW					
Energy	$0.0420	$/kWh	$12.31				

Fuel rate Information:

		$/MBTU	Heating Value		Typical Values
#2 Oil ($/gal)	$0.60	$4.35	137000	BTU/gal	137000
#6 Oil ($/gal)	$0.50	$3.29	152000	BTU/gal	15200
Coal ($/ton)	$38.00	$1.48	12800	BTU/lb	12800

Energy Ratios

Smr. El/Gas:	3.069
Demand/Gas	584.705
Wntr El/Gas:	3.069
Demand/Gas	584.705

	Suggested	
Gas Price	$0.40	$/therm
#2 Oil	$0.60	$/gal
#6 Oil		$/gal
Coal	$0.00	$/ton
Elect	$0.0420	$/kWh

Coal Specifications

Proximate Analysis	As Rec'd	Dry
% Moisture		
% Ash		
% Volatile		
% Fixed C		
BTU/lb		
% Sulfur		
Total	0	0

Ash Fusion Temps	Reducing	Oxidizing
Init Def		
H=W		
H=1/2 W		
Fluid		

Bulk Dens [ ] lbs/ft3

Utlimate Anaysis	As Rec'd	Dry
Moisture		
Carbon		
Hydrogen		
Nitrogen		
Chlorine		
Sulfur		
Ash		
Oxygen (dif)		
Total	0	0

Energy Distribution — Ft Carson

Distribution System Geometry

			Suggested				
Total Area	373,421	acres	373421	acres Total	Bldg ft2/acre	4,435	
Served Area	2,500	acres	12393	acres Impr	Bldg ft2/10K	0.102	
Total Area	1.627E+10	ft2			Energy Dens	0.264	MBTU/hr/acre
Served Area	1.089E+08	ft2			Energy Dens	0.0605	MBTU/hr/10Kft2
					Favoribility	270	MBTU/yr/acre
					Favoribility	0.006	MBTU/yr/10Kft2

Perimeter		ft
Area Length		ft
Area Width		ft

Steam/Hot Water Pipe System

LTHW		linear ft	Pipe System	
HTHW	172,000	linear ft	Buried Steel Pipe	Suggested
Steam		linear ft		172,000 lin Feet

Chill Water Pipe System

Chill Water		linear ft	Pipe System
			Buried Poly Pipe

Energy Use — Ft Carson

Thermal End Use Characterization

							Suggested	
Bldg Area (tot)	11,087,000	ft2	Pk Bldg load	659	MBTU/hr		659	MBTU/hr
			Annual Load	675,521	MBTU/yr		675,521	MBTU/yr
			Pk/Ann Ratio	0.00098	yr/hr		11,087,000	Bldg ft (tot)
			Load Fact	0.11696208				

Electrical End Use Characterization

Base Electric Use		MWhr
Base Peak Electric Load:	75	MW

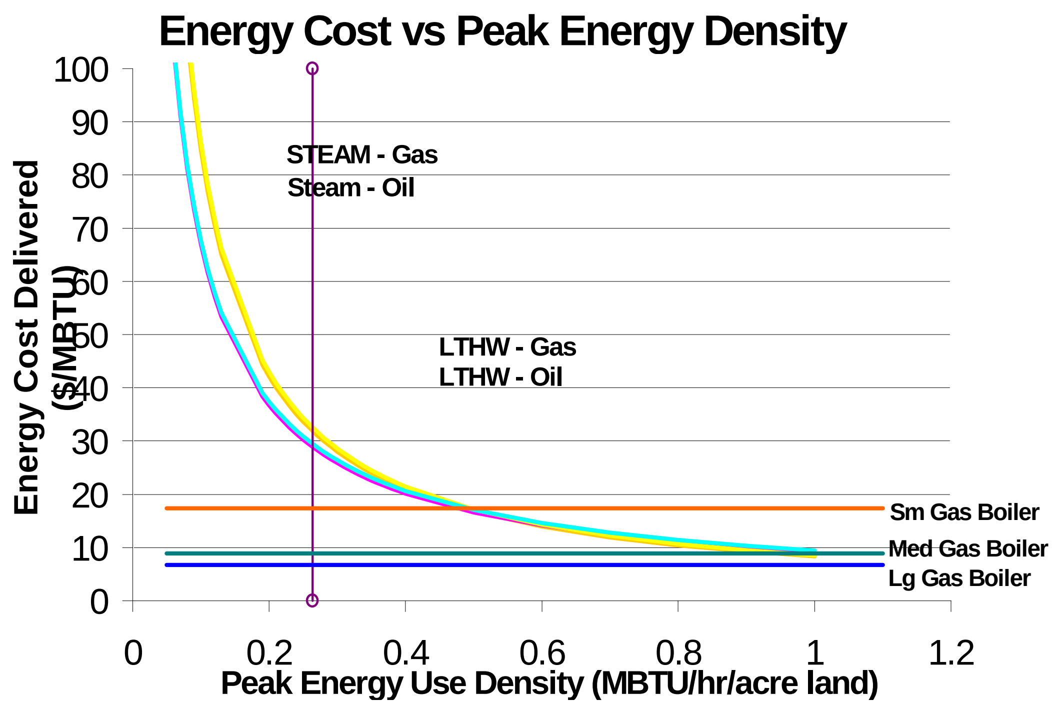
Monthly Peak Electrical Load (% of peak)

Jan	40	Feb	40	Mar	40	Apr	50
May	60	Jun	100	Jul	100	Aug	100
Sep	90	Oct	60	Nov	40	Dec	40

Climate

HDD	6373		CDD	692		
1% Design	2	Deg F	1% DB Temp	92		
Coinc Wind	7	Knots	% Coinc WB	59		
			1% WB Temp	64		

Output Summary **Ft Carson**



Energy Den 0.264 MBTU/hr/acre

	Costs ($.MBTU) Delivered
LTHW (gas)	28.92
LTHW (oil)	29.50
Steam (gas)	31.90
Steam (oil)	32.59
Sm Gas Blr	17.36
Med Gas Blr	8.94
Lg Gas Blr	6.73

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Ft Carson																	
2					$49,128,511													
3	TDAC	TDAC Description	UM	Quantity	Total Cost	Unit Cost												
4	J11000	PURCHASED WATER	KG	845,278	1,163,698	1.38												
5	J12000	FILTERED WATER		453,900	105,511	0.23												
6	J13000	UNFILTERED WATER		0	0	0.00												
7	J21000	PURCHASED SEWAGE DISPOSAL	KG	198,481	423,054	2.13												
8	J22000	WASTEWATER PLANT OPERATION	KG	491,921	578,836	1.18												
9	J22300	INDUSTRIAL WASTEWATER TREATMENT PLANTS		0	0	0.00												
10	J23000	UNTREATED INDUSTRIAL WASTE/COOL WTR		34,617	153,270	4.43												
11	J24000	UNTREATED INDUST WASTE/COOL WT	KG	6,430	8,680	1.35												
12	J31000	PURCHASED ELECTRIC ENERGY	MWH	104,939	4,029,036	38.39					$0.0384	$/Kwhr						
13	J32000	ELEC GEN PLANT OPERATION		0	0	0.00		MBTU	$/MBTU									
14	J40100	PURCHASED GAS	KCF	1,165,735	4,672,877	4.01		1,165,735	$4.01		$0.40	$/therm						
15	J40200	PURCHASED OIL	BL	476	11,911	25.02		2,773	$4.30		$0.60	$/gal						
16	J40300	PURCHASED COAL	TN	0	0	0.00		0	#DIV/0!	Boiler Eff	$0.00	$/ton						
17	J40400	HEAT PLT OPERATION	MB	349,748	380,114	1.09			$1.09	0.30								
18	J40500	PURCHASED STEAM & HOT WATER SERVICI	MB	215,044	289,881	1.35			$1.35									
19	J40600	AIR CONDITIONING PLANT OPERATION	TN	7,043	49,006	6.96												
20	J40700	REFRIGERATION/COLD STORAGE/ICE MAKING		0	0	0.00												
21	J61000	OTHER UTILITIES CONNECTION COSTS		0	0	0.00												
22	J62000	OTHER UTILITIES LESS CONNECTION COSTS		0	124,028	0.00												
23	J63000			0	0	0.00												
24	K11100	WATER SOURCE MAINTENANCE	KGD	4,641	0	0.00												
25	K11200	WATER STORAGE	KG	3,832	0	0.00												
26	K11300	WATER DISTRIBUTION	KLF	962	176,613	183.59												
27	K12100	DOMESTIC WASTEWATER PLANTS	KG	12,081	162,289	13.43												
28	K12200	INDUSTRIAL WASTEWATER TREATMENT PL	KG	1,302	1,621	1.25												
29	K12300	WASTEWATER COLLECTION SYSTEMS (INCI	KLF	629	162,001	257.55												
30	K12400			45	20,616	458.13												
31	K13100	ELECTRIC GENERATING PLANT	KVA	0	0	0.00												
32	K13210	ELEC DISTRIBUTION OVERHEAD	KLF	1,087	337,225	310.23												
33	K13220	ELEC DISTRIBUTION UNDERGROUND	KLF	1,550	13,231	8.54												
34	K13300	ELEC DISTRIBUTION TRANSFORMER	KVA	94,310	0	0.00				Total Elect O&M ($/kwhr)								
35	K13400	EXTERIOR LIGHTING		0	27,272	0.00				$0.0036								
36	K13500	SUBSTATIONS AND SWITCH STATIONS	PLT	5	0	0.00		Plant Size (MBTU/hr)		Total O&M ($/MBTU) fuel used								
37	K14010	GAS FIRED HEAT PLANT	MB	697	278,113	399.01		697		$0.25								
38	K14020	OIL FIRED HEAT PLANT	MB	0	0	0.00		0										
39	K14030			0	0	0.00		0										
40	K14040			6	162	27.00		6	Linear Feet Dist	Total O&M ($/MBTU) sent								
41	K14510	STEAM & HOT WATER DISTRIBUTION	KLF	172	14,000	81.40			172,000	$0.84								
42	K14520			403	250,000	620.35												
43	K14530			2	0	0.00												
44	K15100	AIR CONDITIONING PLANT MAINTENANCE	TN	52,887	46,096	0.87												
45	K15200			0	0	0.00												
46	K16100			0	0	0.00											Design Day	2
47	K16200			0	233	0.00							HDD	6373			DD	63
48	K16300	OTHER UTILITY COSTS		0	1,228	0.00		Peak Btu/hr		Annual MBTU/yr		Heatload Cat	a	b	Btu/ft2/day	ap	bp	Btu/ft2/hr
49	K21000	TRAINING BLDGS	KSF	0	322,411	0.00		0		0		FAM	113.5	10.5	67030	4.729	0.687	48.01
50	K22100	MAINTENANCE BUILDINGS	KSF	1,447	1,590,999	1,099.52		124,783,347		97,305		b1	1320.5	10.53	68428.19	5.438	0.66	47.018
51	K22200	PRODUCTION BUILDINGS	KSF	0	0	0.00		0		0		b2	81.9	7.4	47242.1	3.412	0.30834	22.83742
52	K23000	RESEARCH, DEVELOPMENT AND TEST BUIL	KSF	0	0	0.00		0		0		b3	295.9	10.53	67403.59	12.329	1.42917	102.36671
53	K24000	STORAGE BUILDINGS	KSF	883	185,439	210.01		84,988,494		59,288		AT	75.7	7.02	44814.16	3.154	0.7875	52.7665
54	K25000	HOSPITAL AND MEDICAL BUILDINGS	KSF	725	1,748,872	2,412.24		53,930,938		52,903		D	241.9	0	241.9	10.079	0	10.079
55	K26000	ADMINISTRATIVE BUILDINGS	KSF	987	305,750	309.78		52,080,536		44,232		MED	254.4	11.41	72970.33	10.6	1.0125	74.3875
56	K27000	UNACCOMPANIED PERSONNEL HOUSING BI	KSF	1,990	1,844,176	926.72		107,361,258		118,696		PM	138.25	10.53	67245.94	3.813	1.3083	86.2359
57	K28100	DEPENDENT SCHOOLS	KSF	109	0	0.00		5,751,549		4,885		GYM	73.7	4.39	28051.17	3.071	1.35	88.121
58	K28200	OTHER COMMUNITY BUILDINGS	KSF	994	1,227,998	1,235.41		38,764,012		33,488		C	147	7.02	44885.46	6.125	0.59167	43.40021
59	K29100	FAM HOUSING BLDGS	KSF	2,732	2,229,635	816.12		131,163,320		183,126		W	35.7	10.53	67143.39	1.487	1.50417	96.24971
60	K29200	OTHER BUILDINGS	KSF	1,170	4,371,701	3,736.50		56,171,700		78,425		REC	231.5	5.25	33689.75	9.64	0.466	38.998
61	K29300	WATER PLANT BUILDINGS	KSF	11	8,618	783.45		560,811		555		NCO	231.5	8.75	55995.25	9.646	0.7765	58.5655
62	K29400	WASTEWATER PLANT BUILDINGS	KSF	6	90,878	15,146.33		577,498		403								
63	K29500	ELECTRICAL PLANT BUILDINGS	KSF	12	2,889	240.75		1,154,997	Sum	806	Sum							
64	K29600	HEAT PLANT BUILDINGS	KSF	21	24,571	1,170.05		2,021,244	659,309,703	1,410	675,521							

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
65	K29700	BUILDING INACTIVE	KSF	0	0	0.00												
66	K31000	IMPROVED GROUNDS	AC	12,393	799,687	64.53		12,393	Acres Improv	#######	Bldg ft Total							
67	K32010	OTHER THAN IMPROVED GROUNDS	AC	91,743	5,158	0.06												
68	K32020	TRAINING AREAS	AC	269,285	138	0.00		373,421	Acres Total									
69	K41000			0	0	0.00												
70	K42000	RAILROADS	KLF	55	77,549	1,409.98												
71	K51010	ROADS SURFACED	KSY	3,728	617,553	165.65												
72	K51030	ROADS UNSURFACED	KSY	5,305	47,300	8.92												
73	K51500			2,028	400,000	197.24												
74	K52100			0	0	0.00												
75	K52200	AIRFIELDS SURFACED	KSY	299	0	0.00												
76	K52300			145	0	0.00												
77	K53100	SIDEWALKS	KSY	729	9,845	13.50												
78	K53200	PARKING VEHICULAR	KSY	3,153	165	0.05												
79	K53300	OPEN STORAGE	KSY	206	1,459	7.08												
80	K54110	BRIDGES, ROAD	BRG	6	0	0.00												
81	K54120			10	0	0.00												
82	K54200	BRIDGES & TRESTLES-RAILROAD	BRG	5	0	0.00												
83	K61100	WATERFRONT FACILITIES & WATER\	FAC	0	0	0.00												
84	K61200			12	200,000	#######												
85	K63000	NON-BUILDING FACILITIES		0	87,231	0.00												
86	L10000	ALTERATION & MINOR CONSTRUCT	%	0	4,151,189	0.00												
87	L20000			0	0	0.00												
88	L30000	ALTER & MINOR CONSTRUCTION HOSPITAI		0	0	0.00												
89	L40000	ALTER & MINOR CONSTRUCTION COMMISS		0	0	0.00												
90	M11000	FIREFIGHTERS		0	2,635,345	0.00												
91	M12000	FIRE CHIEFS & INSPECTORS		0	76,663	0.00												
92	M13000			0	565,693	0.00												
93	M21300			0	0	0.00												
94	M21400			0	0	0.00												
95	M21500			10,273	201,674	19.63												
96	M21600	LANDFILL OTHER (COLLECTION THF	TON	0	0	0.00												
97	M21700			30,846	338,696	10.98												
98	M31000	PEST CONTROL, BUILDINGS	KSF	940	4,633	4.93												
99	M32000			0	0	0.00												
100	M40000	CUSTODIAL SERVICE	KSF	1,402	997,250	711.31												
101	M50000	ICE ALLEVIATION		0	106,498	0.00												
102	M61000	MGMT & ENGRING LESS MASTER PL	%	0	6,395,179	0.00												
103	M62000	MASTER PLANNING	%	0	63,590	0.00												
104	M63000	ENVIRONMENTAL PROG-ACTV INSTL		0	3,533	0.00												
105	M71000			0	0	0.00												
106	M72000	REAL ESTATE ADMIN		0	0	0.00												
107	M74000			0	7,993	0.00												
108	M81100	LEASES		0	0	0.00												
109	M81200			0	0	0.00												
110	M81300			0	0	0.00												
111	M82000			0	0	0.00												
112	M84300	EQUIPMENT-IN-PLACE, ACQUISITION/INSTA		0	1,145,491	0.00												
113	M84400	SPECIAL ENGINEERING MAINTENANCE AC		0	7,880	0.00												
114	M85000	FE PACKING AND CRATING ACTIVITIES		0	0	0.00												
115	M86000			0	744,757	0.00												
116	M87000	PURCHASED FACILITY ENGINEERING SERV		0	0	0.00												
117	M88100	MAINTENANCE AND REPAIR OF DPW EQUIF		0	925,523	0.00												
118	M88200			0	0	0.00												
119	M88300			0	0	0.00												
120	M99000	DEMOLITION OF REAL PROPERTY	KSF	151	1,076,300	7,127.81												

Fort Eustis Screening

Advance Energy Screening Analysis	Site General Data

Notice to users:
This sheet is to assist a base or command engineer screen for the economic viability of several energy supply options. To select the most life-cycle cost effective option, a more detailed analysis will need to be conducted. Contact the Utilities Division, USACERL, Champaign, IL 61826-9005 (800)872-2375 ext 5505 or Mechanical and Energy Division, U.S. Army Center for Public Work, Ft Belvoir, VA (703) 806-6067

Front Sheet

	Name	Phone
Site Name:	Ft Eustis	
POC's:		
MACOM POC		

Energy Supply — Ft Eustis

Energy Supply Information
Utility Prices

Natural Gas Utility Rates:

			$/MBTU				
Summer Rate	$0.36	$/therm	$3.60	from		through	
Winter Rate	$0.36	$/therm	$3.60	from		through	

Electric Utility Rates:

			$/MBTU				
Summer Dem.	$8.00	$/kW		from		through	
Ratchet		%		from	Jan	through	Dec
Winter Dem.	$8.00	$/kW					
Energy	$0.0406	$/kWh	$11.90				

Fuel rate Information:

		$/MBTU	Heating Value		Typical Values
#2 Oil ($/gal)	$0.53	$3.87	137000	BTU/gal	137000
#6 Oil ($/gal)	$0.50	$3.29	152000	BTU/gal	15200
Coal ($/ton)	$38.00	$1.48	12800	BTU/lb	12800

Energy Ratios

Smr. El/Gas:	3.305
Demand/Gas	651.296
Wntr El/Gas:	3.305
Demand/Gas	651.296

	Suggested	
Gas Price	$0.36	$/therm
#2 Oil	$0.53	$/gal
#6 Oil		$/gal
Coal	$0.00	$/ton
Elect	$0.0406	$/kWh

Coal Specifications

Proximate Analysis	As Rec'd	Dry
% Moisture		
% Ash		
% Volatile		
% Fixed C		
BTU/lb		
% Sulfur		
Total	0	0

Ash Fusion Temps	Reducing	Oxidizing
Init Def		
H=W		
H=1/2 W		
Fluid		

Bulk Dens ______ lbs/ft3

Utlimate Anaysis	As Rec'd	Dry
Moisture		
Carbon		
Hydrogen		
Nitrogen		
Chlorine		
Sulfur		
Ash		
Oxygen (dif)		
Total	0	0

Energy Distribution Ft Eustis

Distribution System Geometry

			Suggested				
Total Area	9,712	acres	9681	acres Total	Bldg ft2/acre	17,414	
Served Area	428	acres	428	acres Impr	Bldg ft2/10K	0.400	
Total Area	4.231E+08	ft2			Energy Dens	0.786	MBTU/hr/acre
Served Area	1.864E+07	ft2			Energy Dens	0.1804	MBTU/hr/10Kft2
					Favoribility	586	MBTU/yr/acre
					Favoribility	0.013	MBTU/yr/10Kft2

Perimeter		ft
Area Length		ft
Area Width		ft

Steam/Hot Water Pipe System

LTHW		linear ft	Pipe System	
HTHW		linear ft	Above Ground	Suggested
Steam	745,000	linear ft		745,000 lin Feet

Chill Water Pipe System

Chill Water		linear ft	Pipe System
			Buried Poly Pipe

Energy Use — Ft Eustis

Thermal End Use Characterization

							Suggested	
Bldg Area (tot)	7,453,000	ft2	Pk Bldg load	336	MBTU/hr		336	MBTU/hr
			Annual Load	250,759	MBTU/yr		250,759	MBTU/yr
			Pk/Ann Ratio	0.00134	yr/hr		7,453,000	Bldg ft (tot)
			Load Fact	0.08509911				

Electrical End Use Characterization

Base Electric Use		MWhr
Base Peak Electric Load:	75	MW

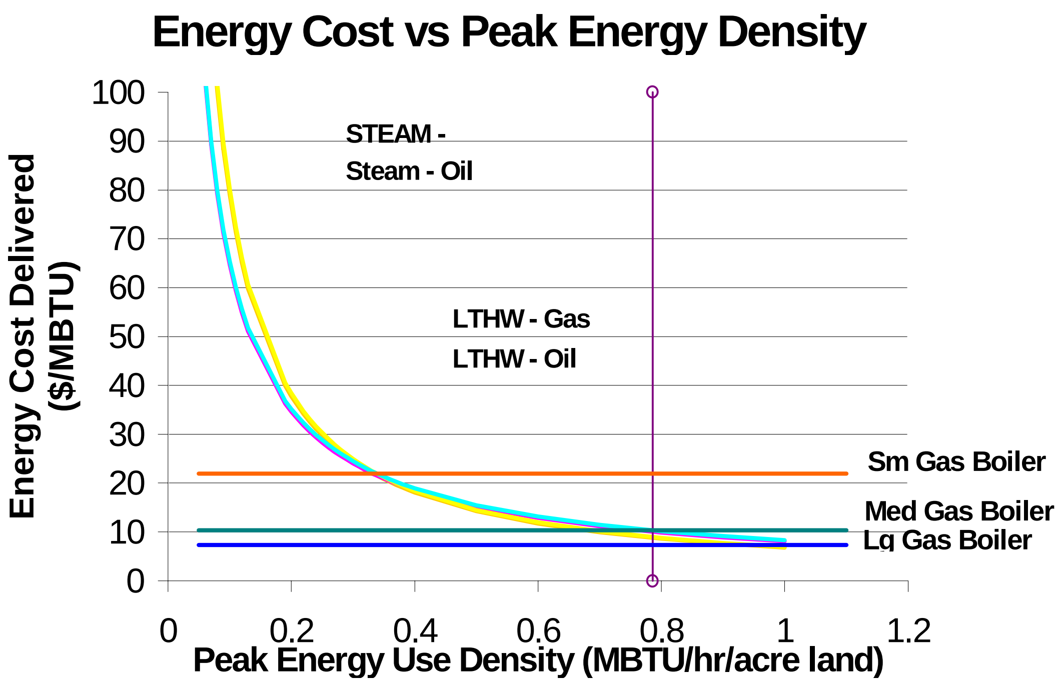
Monthly Peak Electrical Load (% of peak)

Jan	40	Feb	40	Mar	40	Apr	50
May	60	Jun	100	Jul	100	Aug	100
Sep	90	Oct	60	Nov	40	Dec	40

Climate

HDD	3752		CDD	1585		
1% Design	17	Deg F	1% DB Temp	92		
Coinc Wind	10	Knots	% Coinc WB	77		
			1% WB Temp	80		

Output Summary **Ft Eustis**



Energy Den	0.786	MBTU/hr/acre

	Costs ($.MBTU) Delivered
LTHW (gas)	10.08
LTHW (oil)	10.35
Steam (gas)	8.82
Steam (oil)	8.99
Sm Gas Blr	21.94
Med Gas Blr	10.38
Lg Gas Blr	7.34

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	**Ft Eustis**																	
2					$51,570,855													
3	TDAC	TDAC Description	UM	Quantity	Total Cost	Unit Cost												
4	J11000	PURCHASED WATER	KG	645,984	$1,427,973	$2.21												
5	J12000	FILTERED WATER																
6	J13000	UNFILTERED WATER																
7	J21000	PURCHASED SEWAGE DISPOSAL	KG	22,764	$72,635	$3.19												
8	J22000	WASTEWATER PLANT OPERATION	KG	534,375	$559,266	$1.05												
9	J22300	INDUSTRIAL WASTEWATER TREATMENT PLANTS																
10	J23000	UNTREATED INDUSTRIAL WASTE/COOL WTR																
11	J24000	UNTREATED INDUST WASTE/COOL V	KG															
12	J31000	PURCHASED ELECTRIC ENERGY	MWH	117,402	$4,280,153	$36.46					$0.0365	$/Kwhr						
13	J32000	ELEC GEN PLANT OPERATION						MBTU	$/MBTU									
14	J40100	PURCHASED GAS	KCF	465,552	$1,676,964	$3.60		465,552	$3.60		$0.36	$/therm						
15	J40200	PURCHASED OIL	BL	27,509	$607,143	$22.07		160,251	$3.79		$0.53	$/gal						
16	J40300	PURCHASED COAL	TN					0	#DIV/0!	Boiler Eff	$0.00	$/ton						
17	J40400	HEAT PLT OPERATION	MB	252,532	$608,504	$2.41			$2.41	0.40								
18	J40500	PURCHASED STEAM & HOT WATER S	MB	12,265	$85,982	$7.01			$7.01									
19	J40600	AIR CONDITIONING PLANT OPERATI(	TN	230	$16,131	$70.13												
20	J40700	REFRIGERATION/COLD STORAGE/ICE MAKING																
21	J61000	OTHER UTILITIES CONNECTION COSTS		0	$3,817													
22	J62000	OTHER UTILITIES LESS CONNECTION COSTS		0	$95,433													
23	J63000																	
24	K11100	WATER SOURCE MAINTENANCE	KGD	2,628	$0	$0.00												
25	K11200	WATER STORAGE	KG	1,882	$0	$0.00												
26	K11300	WATER DISTRIBUTION	KLF	593	$131,653	$222.01												
27	K12100	DOMESTIC WASTEWATER PLANTS	KG	1,730	$544,141	$314.53												
28	K12200	INDUSTRIAL WASTEWATER TREATM	KG	271,527	$0	$0.00												
29	K12300	WASTEWATER COLLECTION SYSTEI	KLF	531	$35,470	$66.80												
30	K12400																	
31	K13100	ELECTRIC GENERATING PLANT	KVA	1,168	$12,750	$10.92												
32	K13210	ELEC DISTRIBUTION OVERHEAD	KLF	1,214	$309,737	$255.14												
33	K13220	ELEC DISTRIBUTION UNDERGROUNI	KLF	230	$26,524	$115.32												
34	K13300	ELEC DISTRIBUTION TRANSFORMER	KVA	78,056	$73,532	$0.94				Total Elect O&M ($/kwhr)								
35	K13400	EXTERIOR LIGHTING		0	$41,746					$0.0042								
36	K13500	SUBSTATIONS AND SWITCH STATIOI	PLT	4	$23,876	$5,969.00		Plant Size (MBTU/hr)		Total O&M ($/MBTU) fuel used								
37	K14010	GAS FIRED HEAT PLANT	MB	539	$15,123	$28.06		539		$0.58								
38	K14020	OIL FIRED HEAT PLANT	MB	217	$222,577	$1,025.70		217										
39	K14030							0										
40	K14040							0	Linear Feet Dist	Total O&M ($/MBTU) sent								
41	K14510	STEAM & HOT WATER DISTRIBUTIOI	KLF	745	$127,822	$171.57			745,000	$1.45								
42	K14520																	
43	K14530																	
44	K15100	AIR CONDITIONING PLANT MAINTEN/	TN	31,081	$181,232	$5.83												
45	K15200																	
46	K16100																Design Day	17
47	K16200												HDD	3752			DD	48
48	K16300	OTHER UTILITY COSTS		0	$573,981			Peak Btu/hr		Annual MBTU/yr		Heatload (	a	b	Btu/ft2/day	ap	bp	Btu/ft2/hr
49	K21000	TRAINING BLDGS	KSF	1,055	$1,025,281	$971.83		43,206,470		27,868		FAM	113.5	10.5	39509.5	4.729	0.687	37.705
50	K22100	MAINTENANCE BUILDINGS	KSF	571	$668,013	$1,169.90		38,035,109		22,638		b1	1320.5	10.53	40829.06	5.438	0.66	37.118
51	K22200	PRODUCTION BUILDINGS	KSF	9	$50,022	$5,558.00		599,503		357		b2	81.9	7.4	27846.7	3.412	0.30834	18.21232
52	K23000	RESEARCH, DEVELOPMENT AND TE:	KSF	121	$72,490	$599.09		5,576,343		3,516		b3	295.9	10.53	39804.46	12.329	1.42917	80.92916
53	K24000	STORAGE BUILDINGS	KSF	735	$527,074	$717.11		54,160,063		29,065		AT	75.7	7.02	26414.74	3.154	0.7875	40.954
54	K25000	HOSPITAL AND MEDICAL BULDINGS	KSF	196	$765,951	$3,907.91		11,603,200		8,441		D	241.9	0	241.9	10.079	0	10.079
55	K26000	ADMINISTRATIVE BUILDINGS	KSF	635	$627,708	$988.52		26,005,790		16,773		MED	254.4	11.41	43064.72	10.6	1.0125	59.2
56	K27000	UNACCOMPANIED PERSONNEL HOU	KSF	990	$8,607,489	$8,694.43		42,272,085		34,975		PM	138.25	10.53	39646.81	3.813	1.3083	66.6114
57	K28100	DEPENDENT SCHOOLS	KSF	0	$0	$0.00		0		0		GYM	73.7	4.39	16544.98	3.071	1.35	67.871
58	K28200	OTHER COMMUNITY BULDINGS	KSF	865	$733,296	$847.74		27,686,920		17,239		C	147	7.02	26486.04	6.125	0.59167	34.52516
59	K29100	FAM HOUSING BLDGS	KSF	1,542	$4,322,472	$2,803.16		58,141,110		60,924		W	35.7	10.53	39544.26	1.487	1.50417	73.68716
60	K29200	OTHER BUILDINGS	KSF	691	$117,942	$170.68		26,054,155		27,301		REC	231.5	5.25	19929.5	9.64	0.466	32.008
61	K29300	WATER PLANT BUILDINGS	KSF	4	$0	$0.00		162,886		119		NCO	231.5	8.75	33061.5	9.646	0.7765	46.918
62	K29400	WASTEWATER PLANT BUILDINGS	KSF	4	$0	$0.00		294,749		158								
63	K29500	ELECTRICAL PLANT BUILDINGS	KSF	2	$102	$51.00		147,374	Sum	79	Sum							
64	K29600	HEAT PLANT BUILDINGS	KSF	33	$34,978	$1,059.94		2,431,676	336,377,433	1,305	250,759							

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
65	K29700	BUILDING INACTIVE	KSF															
66	K31000	IMPROVED GROUNDS	AC	428	$252,389	$589.69		428	Acres Improved	7,453,000	Bldg ft Total							
67	K32010	OTHER THAN IMPROVED GROUNDS	AC	4,257	$178,465	$41.92												
68	K32020	TRAINING AREAS	AC	4,996	$256,542	$51.35		9,681	Acres Total									
69	K41000																	
70	K42000	RAILROADS	KLF	30	$2,678,058	$89,268.60												
71	K51010	ROADS SURFACED	KSY	737	$182,062	$247.03												
72	K51030	ROADS UNSURFACED	KSY	595	$8,920	$14.99												
73	K51500																	
74	K52100																	
75	K52200	AIRFIELDS SURFACED	KSY	237	$1,256	$5.30												
76	K52300																	
77	K53100	SIDEWALKS	KSY	232	$57	$0.25												
78	K53200	PARKING VEHICULAR	KSY	2,810	$771,873	$274.69												
79	K53300	OPEN STORAGE	KSY	490	$0	$0.00												
80	K54110	BRIDGES, ROAD	BRG	1	$1,458	$1,458.00												
81	K54120																	
82	K54200	BRIDGES & TRESTLES-RAILROAD	BRG	3	$0	$0.00												
83	K61100	WATERFRONT FACILITIES & WATER\	FAC	37	$86,268	$2,331.57												
84	K61200																	
85	K63000	NON-BUILDING FACILITIES		0	$399,313													
86	L10000	ALTERATION & MINOR CONSTRUCT	%	0	$3,781,900													
87	L20000																	
88	L30000	ALTER & MINOR CONSTRUCTION HOSPITALS/M		0	$691,280													
89	L40000	ALTER & MINOR CONSTRUCTION COMMISSARI		9	$12,997	$1,444.11												
90	M11000	FIREFIGHTERS		0	$2,200,167													
91	M12000	FIRE CHIEFS & INSPECTORS		0	$72,038													
92	M13000																	
93	M21300																	
94	M21400																	
95	M21500																	
96	M21600	LANDFILL OTHER (COLLECTION THR	TON	12,461	$647,691	$51.98												
97	M21700																	
98	M31000	PEST CONTROL, BUILDINGS	KSF	6,616	$264,638	$40.00												
99	M32000																	
100	M40000	CUSTODIAL SERVICE	KSF	1,039	$554,705	$533.88												
101	M50000	ICE ALLEVIATION		0	$81,791													
102	M61000	MGMT & ENGRING LESS MASTER PL	%	0	$2,948,119													
103	M62000	MASTER PLANNING	%	0	$35,066													
104	M63000	ENVIRONMENTAL PROG-ACTV INSTL		0	$4,565,553													
105	M71000																	
106	M72000	REAL ESTATE ADMIN		0	$49,773													
107	M74000																	
108	M81100	LEASES		0	$822													
109	M81200																	
110	M81300																	
111	M82000																	
112	M84300	EQUIPMENT-IN-PLACE, ACQUISITION/INSTAL/O		0	$460,561													
113	M84400	SPECIAL ENGINEERING MAINTENANCE ACTIVI		0	$338,520													
114	M85000	FE PACKING AND CRATING ACTIVITIES		0	$54,811													
115	M86000																	
116	M87000	PURCHASED FACILITY ENGINEERING SERVICE		0	$168,013													
117	M88100	MAINTENANCE AND REPAIR OF DPW EQUIPME		0	$1,700													
118	M88200																	
119	M88300																	
120	M99000	DEMOLITION OF REAL PROPERTY	KSF	428	$517,066	$1,208.10												

Fort Riley Screening

Advance Energy Screening Analysis	Site General Data

Notice to users:
This sheet is to assist a base or command engineer screen for the economic viability of several energy supply options. To select the most life-cycle cost effective option, a more detailed analysis will need to be conducted. Contact the Utilities Division, USACERL, Champaign, IL 61826-9005 (800)872-2375 ext 5505 or Mechanical and Energy Division, U.S. Army Center for Public Work, Ft Belvoir, VA (703) 806-6067

Front Sheet

Site Name:	Ft Riley	
	Name	Phone
POC's:		
MACOM POC		

Energy Supply — Ft Riley

Energy Supply Information
Utility Prices

Natural Gas Utility Rates:

			$/MBTU				
Summer Rate	$0.28	$/therm	$2.84	from		through	
Winter Rate	$0.28	$/therm	$2.84	from		through	

Electric Utility Rates:

			$/MBTU				
Summer Dem.		$/kW		from		through	
Ratchet		%		from	Jan	through	Dec
Winter Dem.		$/kW					
Energy	$0.0477	$/kWh	$13.97				

Fuel rate Information:

		$/MBTU	Heating Value		Typical Values
#2 Oil ($/gal)	$0.48	$3.50	137000	BTU/gal	137000
#6 Oil ($/gal)	$0.50	$3.29	152000	BTU/gal	15200
Coal ($/ton)	$38.00	$1.48	12800	BTU/lb	12800

Energy Ratios

Smr. El/Gas:	4.919
Demand/Gas	0.000
Wntr El/Gas:	4.919
Demand/Gas	0.000

Suggested from Redbook

Gas Price	$0.28	$/therm
#2 Oil	$0.00	$/gal
#6 Oil		$/gal
Coal	$0.00	$/ton
Elect	$0.0477	$/kWh

Coal Specifications

Proximate Analysis	As Rec'd	Dry
% Moisture		
% Ash		
% Volatile		
% Fixed C		
BTU/lb		
% Sulfur		
Total	0	0

Ash Fusion Temps	Reducing	Oxidizing
Init Def		
H=W		
H=1/2 W		
Fluid		

Bulk Dens		lbs/ft3

Utlimate Anaysis	As Rec'd	Dry
Moisture		
Carbon		
Hydrogen		
Nitrogen		
Chlorine		
Sulfur		
Ash		
Oxygen (dif)		
Total	0	0

Energy Distribution — Ft Riley

Distribution System Geometry

			Suggested					
Total Area	100,446	acres	100446	acres Total	Bldg ft2/acre	4,566	
Served Area	3,000	acres	60449	acres Impr	Bldg ft2/10K	0.105	
Total Area	4.375E+09	ft2			Energy Dens	0.260	MBTU/hr/acre
Served Area	1.307E+08	ft2			Energy Dens	0.0596	MBTU/hr/10Kft2
					Favoribility	233	MBTU/yr/acre
					Favoribility	0.005	MBTU/yr/10Kft2
Perimeter		ft					
Area Length		ft					
Area Width		ft					

Steam/Hot Water Pipe System

LTHW		linear ft	Pipe System		
HTHW		linear ft	Shallow Trench	Suggested	
Steam	22,000	linear ft		22,000	lin Feet

Chill Water Pipe System

Chill Water		linear ft	Pipe System
			Buried Poly Pipe

Energy Use — Ft Riley

Thermal End Use Characterization

						Suggested	
Bldg Area (tot)	13,698,000	ft2	Pk Bldg load	779	MBTU/hr	779	MBTU/hr
			Annual Load	698,238	MBTU/yr	698,238	MBTU/yr
			Pk/Ann Ratio	0.00112	yr/hr	13,698,000	Bldg ft (tot)
			Load Fact	0.10237053			

Electrical End Use Characterization

Base Electric Use		MWhr
Base Peak Electric Load:	75	MW

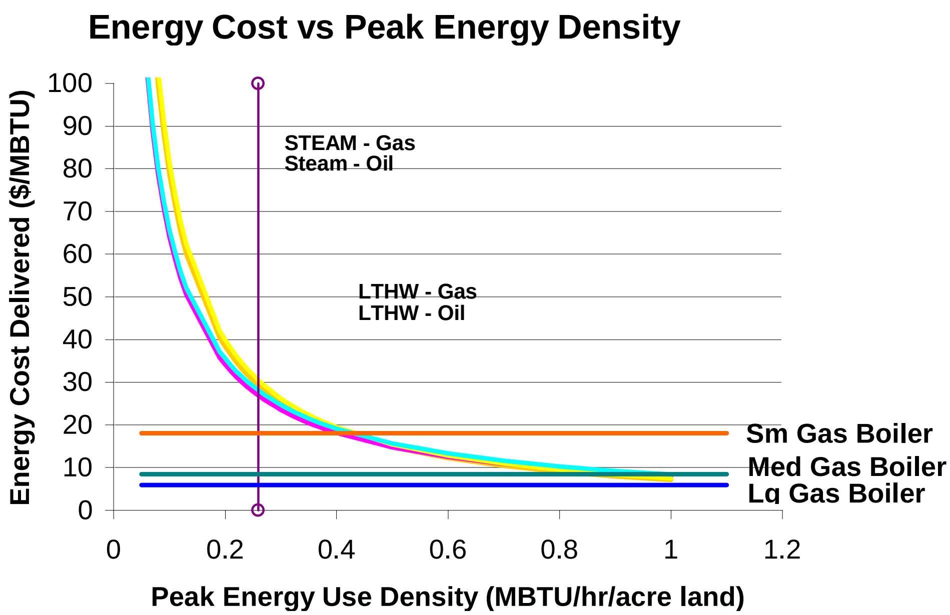
Monthly Peak Electrical Load (% of peak)

Jan	40	Feb	40	Mar	40	Apr	50
May	60	Jun	100	Jul	100	Aug	100
Sep	90	Oct	60	Nov	40	Dec	40

Climate

HDD	5306		CDD	1503	
1% Design	1	Deg F	1% DB Temp	99	
Coinc Wind	8	Knots	% Coinc WB	75	
			1% WB Temp	78	

Output Summary — Ft Riley



Energy Den 0.260 MBTU/hr/acre

	Costs ($.MBTU) Delivered
LTHW (gas)	26.89
LTHW (oil)	28.13
Steam (gas)	29.18
Steam (oil)	30.50

Sm Gas Blr	18.09
Med Gas Blr	8.47
Lg Gas Blr	5.95

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Ft Riley																	
2					$56,125,953													
3	TDAC	TDAC Description	UM	Quantity	Total Cost	Unit Cost												
4	J11000	PURCHASED WATER	KG	0	0	0.00												
5	J12000	FILTERED WATER		151,784	467,857	3.08												
6	J13000	UNFILTERED WATER		3,500	10,491	3.00												
7	J21000	PURCHASED SEWAGE DISPO	KG	0	0	0.00												
8	J22000	WASTEWATER PLANT OPER	KG	73,044	454,546	6.22												
9	J22300	INDUSTRIAL WASTEWATER TREATMEN		0	0	0.00												
10	J23000	UNTREATED INDUSTRIAL WASTE/COO		233,000	27,193	0.12												
11	J24000	UNTREATED INDUST WASTE/	KG	0	0	0.00												
12	J31000	PURCHASED ELECTRIC ENE	MWH	140,136	6,376,185	45.50					$0.0455	$/Kwhr						
13	J32000	ELEC GEN PLANT OPERATION		0	0	0.00		MBTU	$/MBTU									
14	J40100	PURCHASED GAS	KCF	1,446,194	4,107,192	2.84		1,446,194	$2.84		$0.28	$/therm						
15	J40200	PURCHASED OIL	BL	0	0	0.00		0	#DIV/0!		$0.00	$/gal						
16	J40300	PURCHASED COAL	TN	0	0	0.00		0	#DIV/0!	Boiler Eff	$0.00	$/ton						
17	J40400	HEAT PLT OPERATION	MB	1,446,620	204,400	0.14			$0.14	1.00								
18	J40500	PURCHASED STEAM & HOT	MB	0	0	0.00			$0.00									
19	J40600	AIR CONDITIONING PLANT O	TN	15,094	173,630	11.50												
20	J40700	REFRIGERATION/COLD STORAGE/ICE		4,300	12,562	2.92												
21	J61000	OTHER UTILITIES CONNECTION COSTS		0	0	0.00												
22	J62000	OTHER UTILITIES LESS CONNECTION		0	0	0.00												
23	J63000			0	0	0.00												
24	K11100	WATER SOURCE MAINTENAN	KGD	49,654	17,773	0.36												
25	K11200	WATER STORAGE	KG	6,325	22,116	3.50												
26	K11300	WATER DISTRIBUTION	KLF	985	194,180	197.14												
27	K12100	DOMESTIC WASTEWATER PL	KG	8,099	30,830	3.81												
28	K12200	INDUSTRIAL WASTEWATER T	KG	93,623	11,770	0.13												
29	K12300	WASTEWATER COLLECTION	KLF	652	51,775	79.41												
30	K12400			60	15,252	254.20												
31	K13100	ELECTRIC GENERATING PLA	KVA	3,091	19,015	6.15												
32	K13210	ELEC DISTRIBUTION OVERHE	KLF	1,032	126,318	122.40												
33	K13220	ELEC DISTRIBUTION UNDER	KLF	353	56,169	159.12												
34	K13300	ELEC DISTRIBUTION TRANSF	KVA	110,023	25,343	0.23				Total Elect O&M ($/kwhr)								
35	K13400	EXTERIOR LIGHTING		0	56,210	0.00				$0.0022								
36	K13500	SUBSTATIONS AND SWITCH	PLT	11	21,088	1,917.09		Plant Size (MBTU/hr)		Total O&M ($/MBTU) fuel used								
37	K14010	GAS FIRED HEAT PLANT	MB	116	186,548	1,608.17		116		$0.13								
38	K14020	OIL FIRED HEAT PLANT	MB	0	0	0.00		0										
39	K14030			0	0	0.00		0										
40	K14040			0	0	0.00		0	Linear Feet Dist	Total O&M ($/MBTU) sent								
41	K14510	STEAM & HOT WATER DISTRI	KLF	22	281	12.77			22,000	$0.13								
42	K14520			577	122,412	212.15												
43	K14530			0	0	0.00												
44	K15100	AIR CONDITIONING PLANT M	TN	4,122	82,354	19.98												
45	K15200			0	0	0.00												
46	K16100			0	35,972	0.00											Design D	1
47	K16200			0	3,545	0.00							HDD	5306			DD	64
48	K16300	OTHER UTILITY COSTS		0	2,186,006	0.00		Peak Btu/hr		Annual MBTU/yr		Heatload	a	b	Btu/ft2/da	ap	bp	Btu/ft2/hr
49	K21000	TRAINING BLDGS	KSF	334	224,529	672.24		17,887,036		12,466		FAM	113.5	10.5	56826.5	4.729	0.687	48,697
50	K22100	MAINTENANCE BUILDINGS	KSF	1,516	917,409	605.15		132,717,007		84,912		b1	1320.5	10.53	57192.68	5.438	0.66	47.678
51	K22200	PRODUCTION BUILDINGS	KSF	9	7,756	861.78		787,898		504		b2	81.9	7.4	39346.3	3.412	0.30834	23.14576
52	K23000	RESEARCH, DEVELOPMENT	KSF	0	0	0.00		0		0		b3	295.9	10.53	56168.08	12.329	1.42917	103.7959
53	K24000	STORAGE BUILDINGS	KSF	616	363,143	589.52		60,216,390		34,439		AT	75.7	7.02	37323.82	3.154	0.7875	53.554
54	K25000	HOSPITAL AND MEDICAL BUL	KSF	465	477,168	1,026.17		35,061,000		28,270		D	241.9	0	241.9	10.079	0	10.079
55	K26000	ADMINISTRATIVE BUILDINGS	KSF	675	1,441,190	2,135.10		36,148,950		25,194		MED	254.4	11.41	60795.86	10.6	1.0125	75.4
56	K27000	UNACCOMPANIED PERSONN	KSF	1,981	4,477,234	2,260.09		108,361,627		98,548		PM	138.25	10.53	56010.43	3.813	1.3083	87.5442
57	K28100	DEPENDENT SCHOOLS	KSF	327	0	0.00		17,512,158		12,205		GYM	73.7	4.39	23367.04	3.071	1.35	89.471
58	K28200	OTHER COMMUNITY BULDIN	KSF	1,146	2,235,052	1,950.31		46,225,744		32,189		C	147	7.02	37395.12	6.125	0.59167	43.99188
59	K29100	FAM HOUSING BLDGS	KSF	5,441	7,317,373	1,344.86		264,960,377		303,752		W	35.7	10.53	55907.88	1.487	1.50417	97.75388
60	K29200	OTHER BUILDINGS	KSF	1,111	3,296,921	2,967.53		54,102,367		62,023		REC	231.5	5.25	28088	9.64	0.466	39.464
61	K29300	WATER PLANT BUILDINGS	KSF	41	50,911	1,241.73		2,118,345		1,723		NCO	231.5	8.75	46659	9.646	0.7765	59.342
62	K29400	WASTEWATER PLANT BUILDI	KSF	12	78,001	6,500.08		1,173,047		671								
63	K29500	ELECTRICAL PLANT BUILDIN	KSF	6	1,541	256.83		586,623	Sum	335	Sum							
64	K29600	HEAT PLANT BUILDINGS	KSF	18	4,264	236.89		1,759,570	778,618,038	1,006	698,238							

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
65	K29700	BUILDING INACTIVE	KSF	0	0	0.00												
66	K31000	IMPROVED GROUNDS	AC	60,449	1,688,497	27.93		60,449	Acres Improved	13,698,000	Bldg ft Total							
67	K32010	OTHER THAN IMPROVED GR	AC	15,997	54,158	3.39												
68	K32020	TRAINING AREAS	AC	24,000	141,619	5.90		100,446	Acres Total									
69	K41000			0	0	0.00												
70	K42000	RAILROADS	KLF	48	4,330	90.21												
71	K51010	ROADS SURFACED	KSY	3,624	2,782,806	767.88												
72	K51030	ROADS UNSURFACED	KSY	0	4,724	0.00												
73	K51500			1,750	2,467,163	1,409.81												
74	K52100			0	0	0.00												
75	K52200	AIRFIELDS SURFACED	KSY	578	1,083	1.87												
76	K52300			4	294	73.50												
77	K53100	SIDEWALKS	KSY	370	99,624	269.25												
78	K53200	PARKING VEHICULAR	KSY	2,790	72,854	26.11												
79	K53300	OPEN STORAGE	KSY	759	466	0.61												
80	K54110	BRIDGES, ROAD	BRG	12	4,743	395.25												
81	K54120			23	723	31.43												
82	K54200	BRIDGES & TRESTLES-RAILR	BRG	0	0	0.00												
83	K61100	WATERFRONT FACILITIES &	FAC	0	0	0.00												
84	K61200			0	0	0.00												
85	K63000	NON-BUILDING FACILITIES		0	311,927	0.00												
86	L10000	ALTERATION & MINOR CONS	%	0	1,321,566	0.00												
87	L20000			0	0	0.00												
88	L30000	ALTER & MINOR CONSTRUCTION HOS		0	0	0.00												
89	L40000	ALTER & MINOR CONSTRUCTION COM		0	0	0.00												
90	M11000	FIREFIGHTERS		0	1,227,689	0.00												
91	M12000	FIRE CHIEFS & INSPECTORS		0	229,810	0.00												
92	M13000			0	0	0.00												
93	M21300			41	852	20.78												
94	M21400			0	0	0.00												
95	M21500			0	0	0.00												
96	M21600	LANDFILL OTHER (COLLECTI	TON	12,495	1,251,724	100.18												
97	M21700			7,516	151,502	20.16												
98	M31000	PEST CONTROL, BUILDINGS	KSF	12,355	364,280	29.48												
99	M32000			5,072	12,527	2.47												
100	M40000	CUSTODIAL SERVICE	KSF	866	525,714	607.06												
101	M50000	ICE ALLEVIATION		0	10,724	0.00												
102	M61000	MGMT & ENGRING LESS MAS	%	0	5,266,869	0.00												
103	M62000	MASTER PLANNING	%	0	627	0.00												
104	M63000	ENVIRONMENTAL PROG-ACTV INSTL		0	18,721	0.00												
105	M71000			0	0	0.00												
106	M72000	REAL ESTATE ADMIN		0	0	0.00												
107	M74000			0	0	0.00												
108	M81100	LEASES		0	73,381	0.00												
109	M81200			0	0	0.00												
110	M81300			0	0	0.00												
111	M82000			0	0	0.00												
112	M84300	EQUIPMENT-IN-PLACE, ACQUISITION/IN		0	24,024	0.00												
113	M84400	SPECIAL ENGINEERING MAINTENANCE		0	92,887	0.00												
114	M85000	FE PACKING AND CRATING ACTIVITIES		0	77,181	0.00												
115	M86000			0	674,543	0.00												
116	M87000	PURCHASED FACILITY ENGINEERING S		0	530	0.00												
117	M88100	MAINTENANCE AND REPAIR OF DPW E		0	2,973	0.00												
118	M88200			0	212,398	0.00												
119	M88300			0	754,362	0.00												
120	M99000	DEMOLITION OF REAL PROP	KSF	0	204,553	0.00												