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Strategic Plan Outline for the Army Utilities Modernization Program

Fiscal Years 2008–2013

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William T. Brown, John L. Vavrin, Noel L. Potts, Charles P. Marsh, Vincent F. Hock, Alexander M. Zhivov, Franklin H. Holcomb, Chang W. Sohn, and Richard J. Scholze

Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
PO Box 9005
Champaign, IL 61826-9005

Henry C. Gignilliat and Carl F. Zeigler

Facilities and Housing Directorate
Office of the Assistant Chief of Staff for Installation Management
Presidential Towers, NC-1
2511 Jefferson Davis Highway
Arlington, VA 22202

Paul M. Volkman and Cecil W. Jones

Public Works Division
Headquarters, Installation Management Command
Taylor Building, NC-3
2530 Crystal Drive
Arlington, VA 22202

Gary Phetteplace

Cold Regions Research and Engineering Laboratory
U.S. Army Engineer Research and Development Center
72 Lyme Road
Hanover, NH 03755

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Abstract: Utilities privatization is considered the preferred method for modernizing and recapitalizing utility systems in the Army. From Fiscal Year (FY) 1998 to FY 2002, the Army implemented a Utilities Modernization Program that focused on upgrading thermal utilities (i.e., central heating and air-conditioning/refrigeration plants and the respective distribution systems) to the most life-cycle cost-effective technology. The current Utilities Modernization Program from FY08–13 will focus not only on central heating and air-conditioning/refrigeration systems, but also on electric, natural gas, potable water, and wastewater systems. This program is supported by initiatives/actions under the Army Energy and Water Campaign Plan for Installations. This report outlines a candidate program management strategy for the Utilities Modernization Program and outlines best practices for performing life-cycle cost analyses for central energy plants and each type of utility system either exempt from utilities privatization or pending exemption from privatization.

Executive Summary

The big picture

The Utilities Modernization Program will focus on systems *external* to the building as opposed to systems within buildings. In addition, the Utilities Modernization Program planning process should be *problem-driven* instead of solutions-driven. Requirements by the installation should be addressed first and foremost before focusing on the technologies that support those requirements. Once the problems are identified by each installation, then the solutions are better defined.

This report focuses primarily on development of a candidate strategic plan for implementing the FY08-13 Utilities Modernization Program. An effective Utilities Modernization Program strategy should take into consideration the following:

- Non-privatized utility systems that have a high probability of never being privatized;
- Non-privatized utility systems previously deemed uneconomical by privatization contractors but brought up to a sufficient level upgrade to attract privatization contractors to revisit and bid against those systems;
- Sound decision making of project alternatives based on technical assessments and economic analyses;
- Energy supply strategy issues to reflect technological advances for meeting environmental standards, fuel availability forecasts, and expectations of new mission requirements; and
- Energy surety (safety, reliability, and security) issues that should be incorporated into the garrisons' Installation Utilities Management Plan (IUMP).

Headquarters, Installation Management Command (HQ IMCOM) will be centrally managing the funds for the FY08-13 Utilities Modernization Program. A candidate methodology outlines the Utilities Modernization Program planning process as follows:

1. Development of a well-defined Utilities Modernization Program plan addressing, but not limited to, the following:
   a. Present status of Army-owned utility systems (to include inventory and plant replacement value of each system);

   b. Fiscal Program Objective Memorandum (POM) requirements and alternative funding options for modernizing utility systems;
   c. Business rules establishing which installations are eligible or not eligible to participate;
   d. Requirements for selected installations to define DD Form 1391 projects for non-privatized utility systems and heating/air-conditioning and refrigeration plants based on those whose Installation Status Report (ISR) ratings are below satisfactory condition/quality levels; and
   e. Identification of proven, energy-efficient and cost-effective technologies.
2. Prioritization of utility systems exempt from privatization or pending exemption from privatization based on the following evaluation criteria:
   a. ISR cost estimates for bringing systems up to a C-1/Q-1 level rating;
   b. Reported environmental (air or water) NOVs;
   c. Mission dependency impact due to changes in mission requirements; and
   d. Energy savings, in terms of energy per square foot reduction and water consumption reduction.
3. Data call transmitted from HQ IMCOM to the installations announcing the Utilities Modernization Program, with specific guidance on how installations can compete for modernization funds via submissions of DD1391s providing information about their proposed modernization projects. (*Note*: The first year of the Utilities Modernization Program will focus on a top-down driven approach based on the ISR ratings of the candidate utility systems.)
4. Release of design funds only to those installations that received approval of their DD1391s from HQ IMCOM.
5. Establishment of a Utilities Modernization Program Support Team to perform site visits and detailed assessments at installations that were approved for utility system projects under the Utilities Modernization Program, beginning in FY07. The assessments will involve validating those projects that are in the design phase prior to their approval and execution. The site visits/assessments will entail, but not be limited to, the following:
   a. Inventory and inspection of existing equipment (boilers, chillers, etc.);
   b. Distribution system inventory and inspection;
   c. Verification of plant data (annual and peak loads, fuel use, boiler log data, water chemistry data, etc.);
   d. Inspection of corrosion control and cathodic protection systems; and
   e. Development of life-cycle cost analyses for the utility systems in question.

Based on the efforts accomplished in FY06, candidate tasks for FY07 are the following:

1. Site visits and detailed assessments by Utilities Modernization Support Team members to validate projects and to determine the most viable options available to improve each installation's energy supply situation.
2. Re-examination of criteria established for non-privatized utility systems and heating/air-conditioning and refrigeration systems due to changes in the ISR ratings at the end of FY06.
3. Re-examination of the ISR cost estimates to include detailed breakdowns of costs for bringing up those utility systems from a C-3 or C-4 rating to a C-2 rating in accordance with DODI 4170.11.
4. Establishment and refinement of guidance explaining how installations should properly prepare their DD1391 programming documents prior to DD1391 processor generation.
5. Refinement of proven, energy-efficient, and cost-effective technologies applicable to modernization.
6. Review of recapitalization projects that are completed or ongoing under privatization.

Modernization defined

In determining the proper classification of an Operations and Maintenance (O&M) project, the definitions of *modernization*, *restoration*, *sustainment*, and *recapitalization* are often misunderstood for one or the other. *Modernization* is defined by the Office of the Deputy Under Secretary of Defense for Installations and Environment as the alteration of facilities for the sole purpose of implementing new or higher standards, accommodating new functions, or replacing building components that exceed the overall service life of the facilities. *Restoration* is defined as repair and replacement work to fix facilities damaged by inadequate sustainment, excessive age, natural disasters, fires, accidents, or other causes. *Sustainment*, as opposed to restoration and modernization, deals with maintenance and repair activities necessary to maintain an inventory of facilities in good working order. *Recapitalization*, however, includes both restoration and modernization of existing facilities, in which major renovation or reconstruction activities (including replacement of individual facilities) are necessary to keep an existing inventory of facilities modern and relevant in an environment of changing standards and missions. Utilities privatization is considered the preferred method for modernizing and recapitalizing utility systems in the Army. A total of 351 Army utility systems were issued Requests for Proposal under the utilities privatization process. As of 30 September 2006, 116 utility systems were privatized, 38 utility systems were exempt from privatization under Defense Reform Initiative Directive #49, and 120 utility systems were pending exemption from privatization, leaving the remaining 77 utility systems under either open solicitation, negotiation, or pending award status.

Condition assessment of utility systems

The ISR is a tool for determining the condition assessment of each system and subsystem on an Army installation, including heating plant and distribution systems, air-conditioning/refrigeration plant and distribution systems, and source and distribution systems for electrical, natural gas, potable water, and wastewater utilities. The ISR reports condition ratings for each system and subsystem on a C-rating scale, either by mission support level, quality level, quantity level, or overall readiness level. In terms of evaluating mission support, quantity, and readiness, a *C-1*, or green, rating denotes that the system is in excellent condition; a *C-2*, or amber, rating denotes that the system does not fully meet satisfactory standards; a *C-3*, or red, rating indicates the condition of an inadequate system performance; and a *C-4* rating indicates that the system is in failed or failing condition. In terms of evaluating quality, the C-rating scale uses *Q-1* (green), *Q-2* (amber), *Q-3* (red), and *Q-4* (failed/failing).

Mission support C-ratings of the utility subsystems (categorized by facility category group) for each O&M-funded Army installation by Installation Management Command (IMCOM) region, as of 3rd Quarter, Fiscal Year (FY) 2006, are shown in the following Tables: Table ES1 for those installations overseen by the Northeast Region, Table ES2 for those installations overseen by the Northwest Region, Table ES3 for those installations overseen by the Pacific Region, Table ES4 for those installations overseen by the Southeast Region, and Table ES5 for those installations overseen by the Southwest Region.[1] Mission support C-ratings assess the manner in which the facility or system supports the accomplishment of assigned units. Installations will need to establish and maintain, as a minimum, a C-2 condition level status, in accordance with Department of Defense Instruction (DODI) 4170.11 (*Installation Energy Management*), for those utility systems that are not subject to utilities privatization. DODI 4170.11 requires that DoD components achieve, by the end of FY 2008, a 67-year

[1] ISR data for 3rd Quarter FY06 obtained from Office of the Assistant Chief of Staff for Installation Management, *Installation Status Report Website*, http://isr.hqda.pentagon.mil.

recapitalization and sustainment rate in which the readiness of existing facilities is restored to a C-2 status, on average. The systems that are not privatized must compete for limited resources under this recapitalization rate. Heating/air-conditioning and refrigeration systems are subject to Army-funded recapitalization improvements and are not part of the utilities privatization process. The remaining types of utility systems – namely electric, natural gas, potable water, and wastewater – are based on the assumption that privatization will result in upgrades of these systems to industry standards (i.e., equivalent to approximately a C-1 status).

This report focuses, in part, on determining the candidate projects for those Army utility systems and heating/air-conditioning and refrigeration systems eligible under the Army's Utilities Modernization Program for the POM budget cycle for FY08–13, based on the requirement that the utility systems are Active Army-owned, Army Reserve-owned, or Army National Guard-owned and are either exempt from privatization or pending exemption from privatization.

Table ES1. Mission support C-ratings of Army-owned utility systems from Northeast IMCOM region installations, as of 3rd Quarter, FY06.

Utility	Facility Category Group	Description	Northeast													
			ABERDEEN PROVING GROUND	ADELPHI LABORATORY CTR	CARLISLE BARRACKS	FORT BELVOIR	FORT DIX	FORT DRUM	FORT EUSTIS	FORT HAMILTON	FORT LEE	FORT MCNAIR	FORT MEADE	FORT MYER	PICATINNY ARSENAL	WEST POINT MIL RESERVATION
			Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn
Electrical	Electric Source															
	81100	Electric Power Source	N/A	N/A	N/A	N/A	N/A	N/A	C-1	N/A	N/A	N/A	N/A	N/A	C-4	N/A
	81150	Standby Power	C-2	C-1	C-1	C-1	C-1	C-1	C-1	N/A	N/A	N/A	C-4	C-2	N/A	C-1
	Electric Distribution															
	81200	Electric Power Lines	C-2	C-2	C-1	C-3	C-1	C-1	N/A	C-2	N/A	N/A	C-1	C-1	N/A	C-1
	81230	Exterior Lighting	C-1	C-1	C-1	C-2	C-1	C-1	N/A	C-1	N/A	C-1	N/A	C-3	N/A	C-1
	81242	Underground Electric Lines	C-2	C-1	C-1	C-2	C-1	C-1	N/A	C-2	N/A	C-1	C-1	C-1	N/A	C-1
	81300	Power Substation/Switch Facilities	C-1	C-1	C-1	C-1	N/A	C-1	N/A	C-2	N/A	N/A	C-1	N/A	N/A	C-1
Natural Gas	Gas Distribution															
	82400	Gas Transmission Lines	C-1	C-4	C-1	N/A	N/A	C-1	C-1	C-1	C-1	N/A	C-1	N/A	N/A	C-1
Water	Water Source/Treatment															
	84110	Water Treatment Facilities	C-4	N/A	C-1	N/A	C-2	C-3	N/A	N/A	N/A	N/A	C-2	N/A	C-1	C-2
	84125	Filter Plant Facilities	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	84130	Water Source-Potable	C-4	C-1	N/A	C-1	C-1	C-1	N/A	N/A	N/A	N/A	N/A	N/A	C-4	C-4
	84150	Chlorinator Facilities	N/A	N/A	N/A	C-1	N/A	C-3	N/A	N/A	N/A	N/A	N/A	N/A	C-4	C-1
	84410	Water Source-Nonpotable	N/A	N/A	N/A	C-3	C-1	C-1	N/A	N/A	N/A	N/A	C-2	N/A	C-2	N/A
	84450	Chlorinator Facilities-Nonpotable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Water Distribution															
	84200	Water Distribution Lines-Potable	C-3	C-1	C-1	C-3	C-2	C-1	N/A	C-1	N/A	C-1	C-3	C-3	C-1	C-3
	84300	Fire Protection System Lines-Nonpotable	C-1	C-1	C-1	C-1	N/A	C-2	N/A	C-1	N/A	N/A	N/A	C-1	C-2	C-2
	84500	Water Distribution Lines-Nonpotable	C-3	C-1	N/A	C-3	C-1	C-2	C-2	N/A	N/A	N/A	N/A	N/A	C-2	N/A
	Water Storage															
	84600	Water Storage-Potable	C-3	N/A	C-1	C-2	C-1	C-2	N/A	N/A	N/A	N/A	C-2	C-3	C-3	C-2
	84620	Reservoir-Potable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-2	N/A
	84700	Water Storage-Nonpotable	N/A	N/A	N/A	N/A	N/A	C-2	C-2	N/A	N/A	N/A	N/A	N/A	C-3	C-1
	84720	Reservoir-Nonpotable	C-4	C-1	N/A	N/A	C-1	C-2	N/A	N/A	C-1	N/A	N/A	N/A	N/A	C-2
	84730	Fire Protection Ponds	N/A	C-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	84740	Water Retaining Basins	C-1	N/A	C-1	C-1	C-1	C-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-1
Wastewater	Wastewater Treatment and Disposal															
	83110	Primary Wastewater Treatment	N/A	N/A	N/A	N/A	C-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-1	C-3
	83112	Secondary Wastewater Treatment	C-3	N/A	N/A	N/A	C-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	83113	Advanced Wastewater Treatment	C-3	N/A	N/A	N/A	C-1	N/A	N/A	N/A	N/A	N/A	C-1	N/A	N/A	N/A
	83140	Industrial Wastewater Treatment	C-2	C-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-4	N/A
	Wastewater Collection															
	83200	Sewage/Waste Collection Lines	C-3	C-1	C-1	C-3	C-1	C-3	C-1	C-2	N/A	C-1	C-1	C-4	C-1	C-3
Heating/Cooling	Heat/Air-Conditioning Source															
	82100	Heat Source	C-1	C-1	N/A	C-1	C-2	N/A	C-1	C-1	N/A	N/A	C-2	C-1	C-4	C-1
	82600	Refrigeration and AC Facilities	C-1	C-1	N/A	C-1	N/A	N/A	C-1	N/A	N/A	N/A	C-2	N/A	N/A	C-1
	Heat/Air-Conditioning Distribution															
	82200	Heat Distribution Lines	C-3	C-1	N/A	C-1	C-3	N/A	C-3	N/A	C-2	C-4	C-4	C-4	C-4	C-2
	82710	Chilled Water Lines	C-3	C-1	C-1	C-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-3	C-4	N/A

Table ES2. Mission support C-ratings of Army-owned utility systems from Northwest IMCOM region installations, as of 3rd Quarter, FY06.

Utility	Facility Category Group	Description	Northwest									
			DETROIT ARSENAL	DUGWAY PROVING GROUND	FORT CARSON	FORT LEAVENWORTH	FORT LEONARD WOOD	FORT LEWIS	FORT MCCOY	FORT RILEY	ROCK ISLAND ARSENAL	YAKIMA TRAINING CENTER
			Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn
Electrical	Electric Source											
	81100	Electric Power Source	N/A	C-1	N/A	N/A	N/A	N/A	N/A	N/A	C-1	N/A
	81150	Standby Power	C-1	C-1	C-1	C-2	N/A	C-1	C-1	C-1	C-1	N/A
	Electric Distribution											
	81200	Electric Power Lines	N/A	C-2	C-3	N/A	C-2	C-1	N/A	C-1	C-2	C-2
	81230	Exterior Lighting	C-1	C-1	C-2	N/A	C-2	C-1	C-1	C-1	C-3	C-1
	81242	Underground Electric Lines	C-1	C-2	C-2	N/A	N/A	C-1	C-1	C-1	C-3	C-1
	81300	Power Substation/Switch Facilities	C-2	C-1	C-3	N/A	N/A	C-1	N/A	C-1	C-1	N/A
	81350	Electric SW Stat	N/A	N/A	C-4	C-1	N/A	N/A	C-1	N/A	C-2	N/A
	81360	Transformer	C-2	C-1	C-3	C-1	N/A	C-1	N/A	C-1	C-1	C-1
Natural Gas	Gas Distribution											
	82400	Gas Transmission Lines	N/A	C-2	C-2	C-1	N/A	C-1	C-1	C-2	C-1	C-1
Water	Water Source/Treatment											
	84110	Water Treatment Facilities	N/A	C-1	N/A	N/A	C-3	N/A	N/A	C-1	C-1	N/A
	84125	Filter Plant Facilities	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	84130	Water Source-Potable	N/A	C-1	C-2	N/A	C-3	C-2	C-2	C-3	C-1	C-1
	84150	Chlorinator Facilities	N/A	C-1	C-2	N/A	N/A	N/A	C-2	C-1	N/A	N/A
	84410	Water Source-Nonpotable	N/A	C-1	C-3	N/A	N/A	C-1	C-3	N/A	C-3	C-1
	84450	Chlorinator Facilities-Nonpotable	N/A	C-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Water Distribution											
	84200	Water Distribution Lines-Potable	C-1	C-1	C-3	N/A	C-3	C-2	C-2	C-1	C-1	C-1
	84300	Fire Protection System Lines-Nonpotable	C-1	N/A	C-1	N/A	N/A	C-1	C-3	N/A	C-1	C-1
	84500	Water Distribution Lines-Nonpotable	N/A	N/A	C-2	N/A	C-3	C-2	C-2	C-1	N/A	N/A
	Water Storage											
	84600	Water Storage-Potable	N/A	C-1	C-1	N/A	C-3	C-3	C-3	C-1	C-1	C-1
	84620	Reservoir-Potable	N/A	N/A	N/A	N/A	C-3	C-2	C-3	N/A	N/A	C-1
	84700	Water Storage-Nonpotable	N/A	C-1	N/A	N/A	C-1	C-1	C-3	N/A	N/A	C-1
	84720	Reservoir-Nonpotable	C-2	N/A	C-2	N/A	N/A	C-3	C-3	C-1	N/A	N/A
	84730	Fire Protection Ponds	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	84740	Water Retaining Basins	N/A	N/A	N/A	N/A	N/A	C-1	C-3	C-1	N/A	N/A
Wastewater	Wastewater Treatment and Disposal											
	83110	Primary Wastewater Treatment	N/A	N/A	C-1	N/A	C-3	C-3	N/A	N/A	N/A	C-1
	83112	Secondary Wastewater Treatment	N/A	C-1	C-1	N/A	C-3	C-2	N/A	N/A	N/A	C-1
	83113	Advanced Wastewater Treatment	N/A	N/A	C-1	N/A	C-3	N/A	C-2	C-1	N/A	N/A
	83140	Industrial Wastewater Treatment	N/A	C-1	N/A	N/A	C-3	C-1	N/A	N/A	C-1	N/A
	Wastewater Collection											
	83200	Sewage/Waste Collection Lines	C-2	C-1	C-3	N/A	C-3	C-2	C-3	C-1	C-1	C-1
Heating/Cooling	Heat/Air-Conditioning Source											
	82100	Heat Source	N/A	C-1	C-3	C-2	C-1	C-1	N/A	C-1	C-3	N/A
	82600	Refrigeration and AC Facilities	N/A	C-2	C-2	C-1	C-2	N/A	N/A	C-1	C-1	N/A
	Heat/Air-Conditioning Distribution											
	82200	Heat Distribution Lines	C-2	N/A	C-2	C-1	C-1	C-3	N/A	C-1	C-2	C-2
	82710	Chilled Water Lines	C-1	N/A	C-2	N/A	C-2	N/A	N/A	C-2	C-3	N/A

Table ES3. Mission support C-ratings of Army-owned utility systems from Pacific IMCOM region installations, as of 3rd Quarter, FY06.

Utility	Facility Category Group	Description	Pacific			
			CAMP ZAMA	FORT RICHARDSON	FORT WAINWRIGHT	SCHOFIELD BKS MIL RESERVE
			Msn	Msn	Msn	Msn
Electrical	Electric Source					
	81100	Electric Power Source	C-1	C-1	C-4	C-1
	81150	Standby Power	C-1	N/A	C-1	C-2
	Electric Distribution					
	81200	Electric Power Lines	C-2	C-3	C-4	C-3
	81230	Exterior Lighting	C-3	C-1	C-2	C-3
	81242	Underground Electric Lines	C-2	C-1	C-2	C-2
	81300	Power Substation/Switch Facilities	C-1	N/A	C-4	C-2
	81350	Electric SW Stat	C-1	N/A	C-4	C-1
	81360	Transformer	C-1	C-2	C-4	C-1
Natural Gas	Gas Distribution					
	82400	Gas Transmission Lines	C-1	C-1	N/A	N/A
Water	Water Source/Treatment					
	84110	Water Treatment Facilities	N/A	C-2	C-2	C-1
	84125	Filter Plant Facilities	N/A	N/A	N/A	C-1
	84130	Water Source-Potable	C-1	C-4	C-1	C-2
	84150	Chlorinator Facilities	N/A	C-2	N/A	C-1
	84410	Water Source-Nonpotable	N/A	N/A	C-1	C-3
	84450	Chlorinator Facilities-Nonpotable	N/A	N/A	N/A	N/A
	Water Distribution					
	84200	Water Distribution Lines-Potable	C-2	C-1	C-1	C-2
	84300	Fire Protection System Lines-Nonpotable	N/A	C-4	N/A	C-3
	84500	Water Distribution Lines-Nonpotable	C-1	C-4	C-1	C-2
	Water Storage					
	84600	Water Storage-Potable	C-1	C-4	C-3	C-2
	84620	Reservoir-Potable	C-1	C-2	N/A	C-3
	84700	Water Storage-Nonpotable	C-2	C-1	N/A	C-2
	84720	Reservoir-Nonpotable	N/A	N/A	N/A	N/A
	84730	Fire Protection Ponds	N/A	N/A	N/A	N/A
	84740	Water Retaining Basins	C-1	C-2	N/A	N/A
Wastewater	Wastewater Treatment and Disposal					
	83110	Primary Wastewater Treatment	N/A	N/A	N/A	C-2
	83112	Secondary Wastewater Treatment	C-2	N/A	N/A	N/A
	83113	Advanced Wastewater Treatment	N/A	N/A	N/A	C-4
	83140	Industrial Wastewater Treatment	C-1	N/A	N/A	N/A
	Wastewater Collection					
	83200	Sewage/Waste Collection Lines	C-2	C-1	C-1	C-2
Heating/Cooling	Heat/Air-Conditioning Source					
	82100	Heat Source	C-2	C-1	C-3	C-1
	82600	Refrigeration and AC Facilities	C-1	N/A	N/A	C-1
	Heat/Air-Conditioning Distribution					
	82200	Heat Distribution Lines	C-2	C-4	C-3	C-1
	82710	Chilled Water Lines	N/A	N/A	N/A	N/A

Table ES4. Mission support C-ratings of Army-owned utility systems from Southeast IMCOM region installations, as of 3rd Quarter, FY06.

Utility	Facility Category Group	Description	Southeast									
			FORT BENNING	FORT BRAGG	FORT CAMPBELL	FORT GORDON	FORT JACKSON	FORT KNOX	FORT RUCKER	FORT STEWART	HUNTER ARMY AIRFIELD	REDSTONE ARSENAL
			Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn
Electrical	Electric Source											
	81100	Electric Power Source	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-1
	81150	Standby Power	C-1	C-1	C-1	C-2	N/A	C-1	C-1	C-1	C-1	C-1
	Electric Distribution											
	81200	Electric Power Lines	C-1	C-1	C-2	C-3	C-1	N/A	N/A	N/A	N/A	C-1
	81230	Exterior Lighting	C-1	C-2	C-1	C-4	C-1	C-1	C-1	N/A	N/A	C-1
	81242	Underground Electric Lines	C-1	C-2	C-4	C-3	C-1	C-1	N/A	N/A	N/A	C-1
	81300	Power Substation/Switch Facilities	N/A	C-1	C-1	C-4	C-2	N/A	N/A	N/A	N/A	C-1
	81350	Electric SW Stat	N/A	C-1	C-1	N/A	N/A	C-1	N/A	N/A	N/A	C-4
	81360	Transformer	N/A	C-2	C-1	C-4	C-1	C-1	N/A	N/A	N/A	C-1
Natural Gas	Gas Distribution											
	82400	Gas Transmission Lines	C-1	C-4	N/A	N/A	C-2	C-1	N/A	C-1	C-1	C-4
Water	Water Source/Treatment											
	84110	Water Treatment Facilities	C-1	C-2	N/A	C-1	N/A	C-2	N/A	N/A	N/A	C-2
	84125	Filter Plant Facilities	N/A	N/A	N/A	C-2	N/A	N/A	N/A	N/A	N/A	N/A
	84130	Water Source-Potable	C-1	C-3	N/A	C-1	C-1	C-1	N/A	C-2	C-1	C-2
	84150	Chlorinator Facilities	N/A	C-2	N/A	C-1	C-1	N/A	N/A	C-2	C-1	N/A
	84410	Water Source-Nonpotable	C-1	N/A	N/A	N/A	N/A	N/A	C-1	C-1	C-1	N/A
	84450	Chlorinator Facilities-Nonpotable	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-1
	Water Distribution											
	84200	Water Distribution Lines-Potable	C-1	C-3	N/A	C-1	C-1	C-3	N/A	C-2	C-1	C-2
	84300	Fire Protection System Lines-Nonpotable	C-1	C-2	C-1	C-1	N/A	N/A	C-1	N/A	C-1	C-1
	84500	Water Distribution Lines-Nonpotable	C-1	N/A	C-1	C-1	N/A	C-2	N/A	N/A	C-1	C-1
	Water Storage											
	84600	Water Storage-Potable	C-1	C-2	N/A	C-3	C-1	C-2	N/A	C-2	C-1	C-1
	84620	Reservoir-Potable	N/A	C-1	N/A	C-1	N/A	N/A	N/A	N/A	N/A	N/A
	84700	Water Storage-Nonpotable	C-1	N/A	C-1	C-1	C-2	N/A	C-1	N/A	C-1	N/A
	84720	Reservoir-Nonpotable	N/A	C-2	N/A	C-2	C-3	N/A	C-2	N/A	C-1	C-2
	84730	Fire Protection Ponds	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	84740	Water Retaining Basins	C-1	N/A	C-1	N/A	N/A	N/A	N/A	C-2	N/A	C-1
Wastewater	Wastewater Treatment and Disposal											
	83110	Primary Wastewater Treatment	N/A	N/A	N/A	N/A	C-2	C-1	N/A	N/A	N/A	C-1
	83112	Secondary Wastewater Treatment	N/A	C-3	N/A	C-3	N/A	N/A	N/A	C-2	N/A	N/A
	83113	Advanced Wastewater Treatment	N/A	C-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	83140	Industrial Wastewater Treatment	C-1	N/A	N/A	C-1	N/A	N/A	N/A	C-1	N/A	N/A
	Wastewater Collection											
	83200	Sewage/Waste Collection Lines	C-1	C-3	N/A	C-2	C-2	C-3	N/A	C-1	C-1	C-3
Heating/Cooling	Heat/Air-Conditioning Source											
	82100	Heat Source	C-1	C-3	C-2	C-2	C-2	C-2	C-1	C-2	C-1	C-2
	82600	Refrigeration and AC Facilities	N/A	C-1	C-1	C-2	C-3	C-1	N/A	C-2	C-1	C-1
	Heat/Air-Conditioning Distribution											
	82200	Heat Distribution Lines	C-1	C-3	C-3	C-3	C-3	C-1	C-1	C-1	C-1	C-3
	82710	Chilled Water Lines	C-1	C-3	C-3	C-4	C-4	N/A	C-1	C-3	C-1	C-3

Table ES5. Mission support C-ratings of Army-owned utility systems from Southwest IMCOM region installations, as of 3rd Quarter, FY06.

Utility	Facility Category Group	Description	Southwest										
			FORT BLISS	FORT HOOD	FORT HUACHUCA	FORT HUNTER LIGGETT	FORT POLK	FORT SAM HOUSTON	FORT SILL	MCALESTER AAP	NTC AND FORT IRWIN	WHITE SANDS MISSILE RANGE	YUMA PROVING GROUND
			Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn	Msn
Electrical	Electric Source												
	81100	Electric Power Source	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-1	N/A	C-1
	81150	Standby Power	C-1	C-1	N/A	C-1	C-1	C-1	C-1	C-1	C-1	C-2	C-1
	Electric Distribution												
	81200	Electric Power Lines	N/A	C-1	C-1	C-1	C-3	C-3	C-1	C-1	N/A	C-2	C-2
	81230	Exterior Lighting	C-1	C-1	C-1	C-1	C-3	C-2	C-2	C-1	C-1	C-1	C-1
	81242	Underground Electric Lines	N/A	C-1	C-1	C-1	C-3	C-1	C-1	C-1	C-2	C-2	C-2
	81300	Power Substation/Switch Facilities	N/A	C-1	N/A	N/A	N/A	N/A	N/A	C-1	C-1	C-2	C-1
	81350	Electric SW Stat	C-2	C-1	C-1	C-1	C-1	C-1	C-2	N/A	C-3	C-1	C-1
	81360	Transformer	C-3	C-1	C-1	C-1	C-3	C-2	C-1	C-1	C-3	C-1	C-1
Natural Gas	Gas Distribution												
	82400	Gas Transmission Lines	N/A	C-3	C-1	C-1	C-1	C-3	C-3	C-1	C-2	C-3	C-1
Water	Water Source/Treatment												
	84110	Water Treatment Facilities	N/A	N/A	N/A	N/A	C-2	N/A	N/A	C-1	C-2	C-1	C-1
	84125	Filter Plant Facilities	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-1	N/A	N/A	N/A
	84130	Water Source-Potable	N/A	N/A	C-2	C-1	C-3	C-1	N/A	C-1	C-1	C-1	C-1
	84150	Chlorinator Facilities	N/A	N/A	C-2	C-1	N/A	C-1	N/A	C-1	N/A	C-1	C-2
	84410	Water Source-Nonpotable	N/A	N/A	C-3	N/A	C-3	C-2	N/A	N/A	C-3	C-2	C-1
	84450	Chlorinator Facilities-Nonpotable	N/A	N/A	N/A	N/A	C-2	N/A	C-1	N/A	C-1	N/A	N/A
	Water Distribution												
	84200	Water Distribution Lines-Potable	N/A	C-2	C-1	C-1	C-2	C-1	C-1	C-1	C-1	C-1	C-2
	84300	Fire Protection System Lines-Nonpotable	C-1	N/A	N/A	N/A	C-2	C-1	N/A	N/A	C-1	C-1	C-1
	84500	Water Distribution Lines-Nonpotable	N/A	N/A	C-1	C-1	C-2	N/A	N/A	N/A	C-1	C-1	C-2
	Water Storage												
	84600	Water Storage-Potable	N/A	C-2	C-1	C-1	C-1	C-1	C-2	C-1	C-1	C-1	C-2
	84620	Reservoir-Potable	N/A	N/A	C-1	N/A	C-2	N/A	N/A	N/A	N/A	N/A	N/A
	84700	Water Storage-Nonpotable	N/A	C-1	C-1	C-1	C-3	C-1	N/A	N/A	C-1	C-1	C-1
	84720	Reservoir-Nonpotable	N/A	C-3	C-1	C-1	C-1	C-1	N/A	N/A	N/A	C-3	C-2
	84730	Fire Protection Ponds	N/A	C-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	84740	Water Retaining Basins	C-1	N/A	C-2	N/A	N/A	N/A	N/A	C-1	C-1	C-4	N/A
Wastewater	Wastewater Treatment and Disposal												
	83110	Primary Wastewater Treatment	N/A	C-1	N/A	N/A	C-2	C-1	N/A	C-1	C-1	N/A	N/A
	83112	Secondary Wastewater Treatment	N/A	N/A	C-1	N/A	C-1	N/A	N/A	N/A	C-4	C-1	N/A
	83113	Advanced Wastewater Treatment	N/A	C-1	C-2	N/A	C-1	N/A	N/A	N/A	N/A	N/A	N/A
	83140	Industrial Wastewater Treatment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	C-1	C-1	N/A	N/A
	Wastewater Collection												
	83200	Sewage/Waste Collection Lines	N/A	C-3	C-1	C-1	C-2	C-1	C-2	C-1	C-1	C-3	C-2
Heating/Cooling	Heat/Air-Conditioning Source												
	82100	Heat Source	C-1	N/A	C-1	N/A	N/A	C-1	C-1	C-1	C-3	C-3	C-1
	82600	Refrigeration and AC Facilities	C-1	C-1	C-1	N/A	C-1	C-1	C-2	N/A	N/A	C-1	C-1
	Heat/Air-Conditioning Distribution												
	82200	Heat Distribution Lines	N/A	C-2	C-1	N/A	C-3	C-2	C-2	C-1	C-3	C-1	C-1
	82710	Chilled Water Lines	C-1	C-1	C-1	N/A	C-3	C-1	C-2	N/A	N/A	C-1	C-1

Relevance of utilities modernization to Army policy

Utilities modernization is supported by the *Army Energy and Water Campaign Plan for Installations*, which outlines the roadmap for achieving the goals and initiatives established under the *Army Energy Strategy for Installations*. The initiatives and actions related to utilities modernization under the *Army Energy and Water Campaign Plan* are noted in Table ES6. Projected funding amounts for Operation and Maintenance, Army projects under the POM 08-13 Utilities Modernization Program are as follows: $43.9M in FY08; $31.9M in FY09; $35.7M in FY10; $34.7M in FY11; $36.9 in FY12; and $20.8M in FY13. This results in a total of approximately $204M for the entire POM cycle and excludes design funds (allocated for $18M over the POM cycle) and funds for installing electric meters in accordance with *Energy Policy Act of 2005* guidance (allocated for $52M over the POM cycle). The Utilities Modernization Program is included in the Army Energy and Utilities Management Decision Package, which has to be defended each FY to ensure that the following requirements are met:

- Metering of facilities, as required by the *Energy Policy Act of 2005*;
- Support of the Army Campaign Plan, Army Modular Forces, and the Global Defense Posture Realignment as “must-fund” obligations for critical mission requirements;
- Resolution of environmental Notices of Violation (NOVs) to meet new utility plant requirements standards (i.e., National Emission Standards for Hazardous Air Pollutants); and
- Eliminate waste and prevent diversion of resources to pay increased bills for inefficient utility plants/systems.

Table ES6. Army Energy and Water Campaign Plan initiatives and actions related to utilities modernization.

Initiative #	Initiative Description	Action #	Action Description
1	*Eliminate energy inefficiencies that waste natural and financial resources, and do so in a manner that does not adversely impact comfort and quality of the facilities in which Soldiers, families, civilians and contractors work and live.*	6 (section 1.6)	Develop a Utilities Modernization and Recapitalization Program for 100% of Government-owned utilities systems.
2	*Increase the use of energy technologies in construction and major renovation projects that provide the greatest cost-effectiveness, energy efficiency, and support to the Army's environmental objectives.*	6 (section 2.6)	Minimize the impact of fuel cost and availability at installations.
		7 (section 2.7)	Establish an Army utility (electric, natural gas and other fuels) source evaluation program that selects a cost-effective and secure energy source option that includes alternative sources.
		8 (section 2.8)	Implement authorization that allows monies to be retained at the installation-level based on utility savings — to be used for utility projects.
3	*Reduce the dependency on fossil fuels by increasing the use of clean, renewable energy, reducing waste, increasing efficiencies, and improving environmental benefits.*	2 (section 3.2)	Develop all cost-effective on-site renewable generation consistent with mission requirements.
		3 (section 3.3)	Modernize and sustain central energy systems to reduce fossil fuel consumption.
		4 (section 3.4)	Reduce on-site fossil fuel use for building space heating and domestic hot water (e.g., using ground-source heat pumps as a proven technology).
4	*Reduce water use to conserve water resources for drinking and domestic purposes.*	1 (section 4.1)	Assess the current water use, costs, and availability at Army installations to prioritize sites for analysis of water conservation opportunities.
		2 (section 4.2)	Improve the water storage and distribution system integrity.
		5 (section 4.5)	Increase efficiency and reduce losses in process water use (cooling towers, equipment that uses single pass cooling, boiler/steam systems, vehicle wash station, construction).
		6 (section 4.6)	Prioritize projects and develop implementation strategies.
5	*Improve the security and reliability of our energy and water systems in order to provide dependable utility service.*	2 (section 5.2)	Implement energy security plans and continuously improve the Army Energy Security Program.
		3 (section 5.3)	Use current and projected energy sources with greatest potential for availability and economy.

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Preface

This study was conducted for the Office of the Assistant Chief of Staff for Installation Management (OACSIM) under Military Interdepartmental Purchase Request (MIPR) 6EERLG7063, "Utilities Modernization Planning and Support"; Project Requisition No. 135164. The technical monitor was Henry C. Gignilliat, DAIM-FDF-U.

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CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
gallons (U.S. liquid)	3.785412 E-03	cubic meters
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
square feet	0.09290304	square meters

Acronyms

AC	alternating current
AEWRS	Army Energy and Water Reporting System
AGA	American Gas Association
AMC	Army Materiel Command
AMF	Army Modular Forces
ANSI	American National Standards Institute
ARNG	Army National Guard
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materiels
AWCF	Army Working Capital Funds
AWWA	American Water Works Association
BLCC	Basic Life-Cycle Cost
BRAC	Base Realignment and Closure
Btu	British thermal unit
CAD	computer-aided design
CBOD	carbonaceous biological oxygen demand
CHCP	combined heating, cooling, and power
CHP	combined heat and power
CO_2	carbon dioxide
COE	Corps of Engineers
COTS	commercial off-the-shelf
DC	direct current
DDT	drainable, dryable, (pressure) testable
DESC	Defense Energy Support Center
DLA	Defense Logistics Agency
DOC	Directorate of Contracting
DoD	Department of Defense
DOE	Department of Energy

DRID	Defense Reform Initiative Directive
DSIRE	Database of State Initiatives for Renewable Energy
EIA	Energy Information Administration
EPAct05	Energy Policy Act of 2005
ESCO	energy service companies
ESPC	Energy Savings Performance Contract
FEMP	Federal Energy Management Program
FY	fiscal year
GCHP	ground-coupled heat pump
GDPR	Global Defense Posture Realignment
GOCO	Government-owned contractor-operated
GSHP	ground-source heat pump
GWHP	ground water heat pump
HQDA	Headquarters, Department of the Army
HQEIS	Headquarter, Executive Information System
HQ IMCOM	Headquarters, Installation Management Command
HTHW	high-temperature hot water
HVAC	heating, ventilating, and air-conditioning
IEEE	Institute of Electrical and Electronics Engineers
IGPBS	Integrated Global Presence and Basing Strategy
IMCOM	Installation Management Command
ISR	Installation Status Report
IUMP	Installation Utilities Management Plan
KG	kilogram
KV	kilovolt
LCCID	Life Cycle Cost in Design
LMOP	Landfill Methane Outreach Program
LTHW	low-temperature hot water
MCA	Military Construction, Army
M&R	maintenance and repair
MBtu	million British thermal units

MDEP	Management Decision Package
MOPs	manuals of practice
NEMA	National Electrical Manufacturers Association
NES	National Energy Savings
NESHAP	National Emission Standards for Hazardous Air Pollutants
NO_x	nitrogen oxide
NPDES	National Pollutant Discharge Elimination System
O&M	Operations and Maintenance
OMA	Operation and Maintenance, Army
OMB	Office of Management and Budget
OMNG	Operation and Maintenance, National Guard
PAA	Procurement Ammunition Army
PEM	proton exchange membrane (fuel cell)
POM	Program Objective Memorandum
PRV	Plant Replacement Value
PV	photovoltaic
RAMP	Requirements and Management Plan
RFP	Request for Proposal
SDDC	Surface Deployment and Distribution Command
SMDC	Space and Missile Defense Command
SSA	Source Selection Authority
SWHP	surface water heat pump
TES	thermal energy storage
TMA	TRICARE Management Activity
UFC	Unified Facilities Criteria
USAR	United States Army Reserve
WEF	Water Environment Federation
YPG	Yuma Proving Ground

1 Introduction

Background

The Army is one of the largest operators of central heating and cooling plants in the United States. It owns, maintains, and operates, in the United States alone (including Alaska and Hawaii), 399 central heating plants, 431 air-conditioning/refrigeration plants, over 10,200 miles of electric power lines, over 1,050 miles of steam/hot water distribution system piping, over 1,480 miles of natural gas distribution, over 140 miles of chilled water distribution, over 3,200 miles of sewage/wastewater distribution lines, and over 5,800 miles of potable and nonpotable water distribution lines.[1] The replacement value of the Army utility assets is more than $11 billion.[2]

According to a report from the U.S. Department of Energy's (DOE's) Industrial Technologies Program, 45 percent of the total energy use in the U.S. manufacturing and mining industries is attributed to steam system losses (20 percent due to boiler losses, 15 percent due to distribution losses, and 10 percent due to energy conversion losses; DOE 2004). Conversely, a steam heat distribution system study at Hawthorne Army Depot, NV, concluded that 57 percent of the total steam leaving the plant was attributed to steam and condensate leaks, heat losses, and unnecessary overheating of buildings due to poor control (Phetteplace 1995). So those losses were 12 percent greater than those reported by the U.S. manufacturing and mining sectors. Additionally, environmental compliance regulations will require stricter adherence. These regulations include the U.S. Environmental Protection Agency's National Emission Standards for Hazardous Air Pollutants (NESHAP) applied to industrial, commercial, and institutional boilers and process heaters, and the Clean Air Mercury Rule applied to utilities for the purpose of regulating mercury emissions.

The Army previously implemented utilities modernization projects from Fiscal Year (FY) 1998 to FY 2002 and invested $60 million per year in the program for a total of 5 years. The program focused on upgrading the thermal utilities to the most life-cycle cost-effective technology. Central

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1 Inventory of Army-owned utility systems obtained from Headquarters, Executive Information System (HQEIS), 2nd Quarter, FY06.

2 Replacement value based on Army-owned utility system data obtained from HQEIS, 2nd Quarter, FY06.

heating and cooling plants and the associated distribution systems were assessed and compared to other alternatives such as decentralized production, low temperature hot water distribution, hybrid energy plants, and privatization. Previous utilities modernization analyses included the non-hardware portions of the energy supply system such as available workforce, workforce skills and knowledge, plant operational procedures, utility and fuel security constraints, and end-user load requirements.

The current Utilities Modernization Program is supported by the following initiatives/actions cited under the *Army Energy and Water Campaign Plan for Installations* (OACSIM 2006):

- Initiative #1: Eliminate energy inefficiencies that waste natural and financial resources, and do so in a manner that does not adversely impact comfort and quality of the facilities in which Soldiers, families, civilians and contractors work and live.
  - Action #6 (section 1.6): Develop a Utilities Modernization and Recapitalization Program for 100 percent of Government-owned utilities systems.
- Initiative #2: Increase the use of energy technologies in construction and major renovation projects that provide the greatest cost-effectiveness, energy efficiency and support to the Army's environmental objectives.
  - Action #6 (section 2.6): Minimize the impact of fuel cost and availability at installations.
  - Action #7 (section 2.7): Establish an Army utility (electric, natural gas, and other fuels) source evaluation program that selects a cost-effective and secure energy source option that includes alternative sources.
  - Action #8 (section 2.8): Implement authorization that allows monies to be retained at the installation-level based on utility savings – to be used for utility projects.
- Initiative #3: Reduce the dependency on fossil fuels by increasing the use of clean, renewable energy, reducing waste, increasing efficiencies, and improving environmental benefits.
  - Action #2 (section 3.2): Develop all cost-effective on-site renewable generation consistent with mission requirements.
  - Action #3 (section 3.3): Modernize and sustain central energy systems to reduce fossil fuel consumption.

    - Action #4 (section 3.4): Reduce on-site fossil fuel use for building space heating and domestic hot water (e.g., using ground-source heat pumps as a proven technology).
- Initiative #4: Reduce water use to conserve water resources for drinking and other domestic purposes.
    - Action #1 (section 4.1): Assess the current water use, costs, and availability at Army installations to prioritize sites for analysis of water conservation opportunities.
    - Action #2 (section 4.2): Improve water storage and distribution system integrity.
    - Action #5 (section 4.5): Increase efficiency and reduce losses in process water use (cooling towers, equipment that uses single pass cooling, boiler/steam systems, vehicle wash stations, construction).
    - Action #6 (section 4.6): Prioritize projects and develop implementation strategies.
- Initiative #5: *Improve the security and reliability of our energy and water systems in order to provide dependable utility service.*
    - Action #2 (section 5.2): Implement energy security plans and continuously improve the Army Energy Security Program.
    - Action #3 (section 5.3): Use current and projected energy sources with greatest potential for availability and economy.

Based on previous experience in Utilities Modernization, the Office of the Assistant Chief of Staff for Installation Management (OACSIM) has requested the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) to support the following:

- prioritization of Army utility systems exempt or pending exemption from utilities privatization;
- development of a candidate Utilities Modernization Program management strategy in preparation for FY08;
- best DD1391 practices for performing life-cycle cost analyses for central heating/cooling plant and distribution systems and for each type of Army utility system that is exempt or pending exemption from utilities privatization;
- identification of project alternatives for modernizing utility systems; and
- recommendation of proven, energy-efficient and cost-effective technologies.

Objectives

The objectives of this study are as follows:

1. Prioritize Army utility systems (electric, natural gas, water, and wastewater) that are exempt from utilities privatization or pending exemption from privatization.
2. Prioritize central heating/air-conditioning and refrigeration plants.
3. Outline a candidate program management strategy for the Utilities Modernization Program for FY08–13.
4. Outline best practices for performing life-cycle cost analyses for central energy plants and for each type of utility system either exempt from utilities privatization or pending exemption from privatization.
5. Identify project alternatives for modernizing utility systems.
6. Identify proven, energy-efficient and cost-effective technologies, and provide ways of implementing these technologies.

Approach

ERDC-CERL organized a project delivery team (PDT) consisting of utility systems experts, to include: heating, cooling, water, wastewater, power plant, and distribution system researchers. The PDT provided an initial evaluation of Active Army-owned, Army Reserve-owned, and Army National Guard-owned heating/air-conditioning and refrigeration plants and utility systems that are exempt from utilities privatization or pending exemption, and determined prioritization of those utility systems. The PDT also outlined the FY08-13 Utilities Modernization Program strategy, covering methodology and considerations for strategy implementation, metrics of success, project selection criteria, identification of project alternatives, and financing requirements and energy incentives to cost-effectively implement the project alternatives. During the course of the effort performed in FY06, the PDT collected supplemental information provided in the Appendixes of this report, ranging from criteria for prioritization of utility systems (Appendix A), to sensitivity analyses (Appendix B), to documentation of proven, energy-efficient, and cost-effective technologies (Appendix H).

Mode of Technology Transfer

The results of this work will be presented to OACSIM and the Installation Management Command (IMCOM) for their consideration in planning and providing management oversight for the FY08-13 Utilities Modernization

Program. It is anticipated that the results of this work will contribute to further awareness by IMCOM's installations, as well as by Corps, District, and other Army installation personnel, via implementation through the associated regional IMCOM offices. This information was presented at the Army Energy Forum in conjunction with the 2006 World Energy Engineering Congress conference in Washington, DC.

This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

2 Considerations and Candidate Methodology for a Utilities Modernization Program Strategy

Army utilities privatization status

Utilities privatization is defined by the Office of the Deputy Under Secretary of Defense for Installations and Environment [DUSD(I&E)] as “a method by which military installations can obtain safe, technologically current, and environmentally sound utility systems, at a relatively lower cost than they would under continued government ownership.” Military installations, as a result of the privatization process, can shift from the role of owner-operators to that of smart utility service customers. Table 1 summarizes status of the Army’s utilities privatization process, as of 30 June 2006, based on 351 utility systems that were issued Requests for Proposal (RFPs).

Table 1. Army utilities privatization process summary as of 30 June 2006.

Privatization Category	Number of Utility Systems	%
Privatized	116	33.0
Pending Award	1	0.3
Exempt Under DRID 49	38	10.8
Pending Exemptions	120	34.2
Negotiating	31	8.8
Open Solicitations	2	0.6
RFP Under Development	43	12.3
Deferred Systems (GOCO & Small)	0	0.0
Totals	351	100.0

The 116 privatized Army utility systems, as of 30 September 2006, are listed in Table 2.

Table 2. Army utility systems currently privatized.

Installation	Utility	Contract Award	New Provider	Contract Administration Agency
Aberdeen Proving Ground MD	Natural Gas	Aug-2000	Baltimore Gas & Electric Co.	ACA Local DOC
Aberdeen Proving Ground MD	Potable Water	7/8/1999	City of Aberdeen	ACA Local DOC
Aberdeen Proving Ground MD	Wastewater	7/8/1999	City of Aberdeen	ACA Local DOC
Aberdeen Proving Ground (Edgewood Area) MD	Natural Gas	Oct-2000	Baltimore Gas & Electric Co.	ACA Local DOC
Adelphi Labs MD	Natural Gas	1970	Washington Gas & Light	DPW
Blue Grass Army Depot, KY	Natural Gas	Dec-1989	Delta Gas Co.	JMC (Under AMC)
Detroit Arsenal, MI	Natural Gas	12/12/1998	Consumers Power Co.	TACOM (Under AMC)
Devens Reserve Forces Training Area MA	Electric	5/1/1996	New England Power Co.	Local Reuse Authority (LRA)
Devens Reserve Forces Training Area MA	Natural Gas	5/1/1996	N. U. Select Energy	Local Reuse Authority (LRA)
Devens Reserve Forces Training Area MA	Potable Water	5/1/1996	EarthTech & US Filter	Local Reuse Authority (LRA)
Devens Reserve Forces Training Area MA	Wastewater	5/1/1996	EarthTech & US Filter	Local Reuse Authority (LRA)
Fort A.P. Hill VA	Electric	7/24/2002	Rappahannock Electrical Coop.	Capital District Contracting Center
Fort Belvoir VA	Natural Gas	11/30/1993	Washington Gas Co.	Capital District Contracting Center (CDCC)
Fort Belvoir VA	Electric	9/25/2006	Dominion Virginia Power	DESC
Fort Benning GA	Electric	1/14/1999	Flint Electric Membership Corp.	Fort Benning DOC (under ACA)
Fort Benning GA	Natural Gas	10/24/2001	United Cities Gas Co.	Fort Benning DOC (under ACA)
Fort Benning GA	Potable Water	9/28/2004	Columbus Water Works	Fort Benning DOC (under ACA)
Fort Benning GA	Wastewater	9/28/2004	Columbus Water Works	Fort Benning DOC (under ACA)
Fort Bliss TX	Electric	9/26/2002	Rio Grande Electric Coop.	ACA
Fort Bliss TX	Natural Gas	3/5/2003	Southern Union Gas Co.	ACA
Fort Bliss TX	Potable Water	6/21/2004	American State Utility Service, Inc.	ACA
Fort Bliss TX	Wastewater	6/21/2004	American State Utility Service, Inc.	ACA
Fort Bragg NC	Electric	2/14/2003	Sandhill Utility Services	DOC Fort Bragg/FY06 Potable Water
Fort Campbell KY	Natural Gas	9/30/2002	City of Clarksville, TN	DOC Fort Campbell
Fort Campbell KY	Potable Water	6/11/2003	CH_2 M. Hill	DOC Fort Campbell
Fort Campbell KY	Wastewater	6/11/2003	CH_2 M. Hill	DOC Fort Campbell
Fort Detrick MD	Natural Gas	12/14/2000	Washington Gas & Light	DESC
Fort Dix NJ	Electric	4/9/1996	Jersey Central Power & Light	Local DOC
Fort Dix NJ	Natural Gas	5/30/1995	Public Service Electric & Gas	Local DOC
Fort Eustis VA	Electric	6/24/2004	Dominion VA Power	ACA Regional DOC at Eustis
Fort Eustis VA	Natural Gas	9/22/1988	Virginia Natural Gas	GSA
Fort Eustis VA	Potable Water	9/29/2005	American States Utility Services	DESC
Fort Eustis VA	Wastewater	9/29/2005	American States Utility Services	DESC
Fort Gordon GA	Natural Gas	5/22/2003	Atlanta Gas Lighting Co.	DOC Fort Gordon
Fort Gordon GA	Electric	9/22/2006	Georgia Power Compnay	DESC
Fort Irwin CA	Electric	4/1/2003	So. California Edison	Fort Irwin Acquisition Command
Fort Irwin CA	Potable Water	1/10/2005	CH_2M Hill	COE Fort Worth District
Fort Irwin CA	Wastewater	1/10/2005	CH_2M Hill	COE Fort Worth District
Fort Knox KY	Electric	5/25/2001	Nolin Rural Electric Coop.	DOC Fort Knox
Fort Knox KY	Wastewater	9/30/2004	Hardin County Water District #1	DOC Fort Knox

Installation	Utility	Contract Award	New Provider	Contract Administration Agency
Fort Leavenworth KS	Electric	9/30/2005	Leavenworth-Jefferson Electric Coop.	COE Kansas City District
Fort Leavenworth KS	Potable Water	9/26/2003	American Water Services Inc.	ACA Local DOC
Fort Leavenworth KS	Wastewater	9/26/2003	American Water Services Inc.	ACA Local DOC
Fort Lee VA	Electric	6/24/2004	Dominion VA Power	Local DOC
Fort Lee VA	Potable Water	1/9/2001	Virginia American Water Co.	ACA Fort Lee DOC
Fort Lee VA	Wastewater	9/29/2005	American States Utility Services	DESC
Fort Leonard Wood MO	Electric	7/18/2003	Lacled Electric Co.	ACA Local DOC
Fort Leonard Wood MO	Natural Gas	8/1/1993	Omega Pipeline Co.	ACA Local DOC
Fort Lewis WA	Natural Gas	1988	Puget Sound Energy	ACA Local DOC
Fort McCoy WI	Electric	4/5/2000	Northern States Power Co.	ACA Local DOC
Fort McCoy WI	Natural Gas	5/1/1997	Xcel Energy	ACA Local DOC
Fort McNair DC	Natural Gas	2/14/2003	Washington Gas & Light	Capital District Contracting Center
Fort McNair DC	Electric	9/25/2006	Dominion Virginia Power	DESC
Fort Meade MD	Electric	4/16/2003	Baltimore Gas & Electric Co.	COE Baltimore District
Fort Meade MD	Natural Gas	4/16/2003	Baltimore Gas & Electric Co.	COE Baltimore District
Fort Monmouth NJ	Natural Gas		New Jersey Natural Gas	CECOM Acquisition Center
Fort Monroe VA	Electric	6/24/2004	Dominion VA Power	ACA Regional DOC at Eustis
Fort Monroe VA	Potable Water	9/29/2005	American States Utility Services	DESC
Fort Monroe VA	Wastewater	9/29/2005	American States Utility Services	DESC
Fort Myer VA	Natural Gas		Washington Gas Energy Services	Capital District Contracting Center (CDCC)
Fort Myer VA	Electric	9/25/2006	Dominion Virginia Power	DESC
Fort Pickett VA	Electric	6/20/2000	Southside Electric Coop.	Local DOC
Fort Pickett VA	Potable Water		City of Blackstone	Local DOC
Fort Rucker AL	Electric	5/22/2003	Alabama Power Co.	DESC
Fort Rucker AL	Natural Gas	4/24/2003	Southeast Alabama Gas	DESC
Fort Rucker AL	Potable Water	9/25/2003	American Water Services Inc.	DESC
Fort Rucker AL	Wastewater	9/25/2003	American Water Services Inc.	DESC
Fort Sam Houston TX	Electric	11/17/2003	City Public Services	ACA
Fort Sam Houston TX	Natural Gas	9/10/1999	City of San Antonio	ACA
Fort Sill OK	Natural Gas	4/3/2001	Oklahoma Natural Gas	ACA Southern Region
Fort Sill OK	Potable Water	5/29/2003	American Water Services Co.	ACA Southern Region
Fort Sill OK	Wastewater	5/29/2003	American Water Services Co.	ACA Southern Region
Fort Stewart GA	Electric	3/2/2004	Canoochee Electrical Membership Corp.	DOC Fort Stewart
Fort Story VA	Electric	6/24/2004	Dominion VA Power	ACA Regional DOC at Eustis
Fort Story VA	Natural Gas	10/15/1995	Virginia Natural Gas	Local DOC
Fort Story VA	Potable Water	9/29/2005	American States Utility Services	DESC
Fort Story VA	Wastewater	9/29/2005	American States Utility Services	DESC
Hawaii	Electric	6/29/2004	Light Company City Public Service	ACA Hawaiian Region
Hawaii	Potable Water	12/18/2003	Pural Water Company	ACA Hawaiian Region
Hunter Army Airfield GA	Electric	3/2/2004	Canoochee Electrical Membership Corp.	DOC Fort Stewart
Letterkenny Army Depot PA	Potable Water	9/14/1998	Franklyn County General Authority	Local DOC
Letterkenny Army Depot PA	Wastewater	9/14/1998	Franklyn County General Authority	Local DOC
Military Ocean Terminal Sunny Point	Electric	9/30/2003	Brunswick Electric Membership Corp.	SDDC

Installation	Utility	Contract Award	New Provider	Contract Administration Agency
Soldier Systems Center, Natick MA	Electric	9/28/2006	NSTAR	DESC
Ord Military Community CA	Electric	3/27/1997	Pacific Gas & Electric	ACA Southern Region
Ord Military Community CA	Natural Gas	3/27/1997	Pacific Gas & Electric	ACA Southern Region
Ord Military Community CA	Potable Water	12/8/2000	Marina Coast Water District	ACA Southern Region
Ord Military Community CA	Wastewater	12/8/2000	Marina Coast Water District	ACA Southern Region
Parks Reserve Forces Training Area CA	Electric	12/19/1985	Pacific Gas & Electric	ACA West region
Parks Reserve Forces Training Area CA	Natural Gas	12/19/1985	Pacific Gas & Electric	ACA West region
Parks Reserve Forces Training Area CA	Potable Water	6/1/1999	Dublin San Ramon District	ACA West region
Parks Reserve Forces Training Area CA	Wastewater	6/1/1999	Dublin San Ramon District	ACA West region
Picatinny Arsenal NJ	Electric	9/30/2002	Sussex Rural Electric Coop. Co.	TACOM-ADEC Picatinny Center for Contracting
Picatinny Arsenal NJ	Natural Gas		New Jersey Natural Gas	TACOM-ADEC Picatinny Center for Contracting
Presidio of Monterey CA	Electric	9/24/2002	City of Monterey	ACA Southern Region
Presidio of Monterey CA	Natural Gas	9/24/2002	City of Monterey	ACA Southern Region
Presidio of Monterey CA	Potable Water	12/20/2001	California American Water Co.	ACA Southern Region
Presidio of Monterey CA	Wastewater	12/20/2001	California American Water Co.	ACA Southern Region
Red River Army Depot TX	Electric	1/11/2002	SW Electric Power Co.	RRAD Contracting Office (AMC Auto. Comm.)
Red River Army Depot TX	Potable Water	5/1/2002	Red River Redevelopment Authority	RRAD Contracting Office (AMC Auto. Comm.)
Red River Army Depot TX	Wastewater	5/1/2002	Red River Redevelopment Authority	RRAD Contracting Office (AMC Auto. Comm.)
Redstone Arsenal AL	Wastewater	6/29/2005	PDR Properties Inc.	US Army Aviation & Missile Command Acquisition Center
Schofield Barracks HI	Wastewater	12/30/2003	Aqua Water Services Co.	ACA Hawaiian Region
Sierra Army Depot CA	Electric	3/1/2004	Plumas Sierra Rural Electrical Coop.	DOC Sierra AD
Sierra Army Depot CA	Natural Gas	9/30/1996	Texas Ohio West	DOC Sierra AD
Soldier Systems Center, Natick MA	Natural Gas	9/30/2000	NSTAR	Local DOC
Stewart Army Subpost GA	Natural Gas	7/30/1999	Central Hudson Gas & Electric	None - subpost has been divested
Tooele Army Depot UT	Natural Gas	Nov1999	Questar Gas Co.	JMC (Under AMC)
Vancouver Barracks WA	Natural Gas		Northwest Gas Co.	ACA Local DOC
Walter Reed Army Medical Center DC	Natural Gas		Washington Gas Co.	No Contract
Yakima Training Center WA	Natural Gas	1988	Cascade Natural Gas	ACA Local DOC

Considerations

In developing an effective Installation Utilities Modernization Program (IUMP) strategy, the following considerations need to be examined.

Non-privatized utility systems that will never be privatized

Consideration must be given as to whether there are a number of non-privatized utility systems that have a high probability of never being privatized, regardless if those are C-4 systems that would be brought up to either a C-2 or C-3 level. If that is the case, then a strategy objective would be to optimize the number of utility systems rated C-1/Q-1 within a limited

Army Program Objective Memorandum (POM) budget. Another option would be to avoid any installation being below C-2/Q-2. The focus would define program emphases, which may differ depending on the focus.

Non-privatized utility systems that were not pursued by privatization contractors

Another item to consider is why privatization contractors did or did not pursue certain non-privatized utility systems at selected installations. If this case is applied only for those systems that were *not* pursued by contractors, then a strategy objective could be to upgrade selected non-privatized utility systems to a sufficient level to attract privatization contractors to revisit and bid for those systems, with the contractors investing their own capital to bring up these systems the rest of the way to a C-1/Q-1 level.

Technical assessments and economic analyses for decision making

In the case of central heating and air-conditioning plant and distribution systems, the life of a plant is not limited by its nominal design life, but is limited by the cost of continuing to operate that plant while meeting certain technical, economic, and environmental performance requirements compared to the cost of other available options (such as direct purchase of power or steam from other sources, construction of a new plant, or decentralization). Consideration of modernization includes technical assessments and economic analyses similar to those used when building a new plant or decentralizing. As with new construction, plant/distribution performance (e.g., efficiency, availability, reliability) and cost factors (e.g., capital equipment, operation, and maintenance) must be incorporated with the safety, environmental, regulatory, funding, Department of Defense (DoD) energy policy (e.g., privatization, *Army Energy Strategy for Installations*, *Army Energy and Water Campaign Plan*), and fuel purchasing issues to make logical modernization decisions (Brewer et al. 1999).

Energy supply strategy issues

For those installations selected under the Utilities Modernization Program, it is crucial that energy supply strategies be developed. These energy supply strategies should reflect technological advances for meeting environmental standards, forecasts of availability of fuel, and expectations of new mission requirements. Coal use by all sectors other than electrical generation has been greatly reduced over the past several decades due to coal use's air pollution implications. Furthermore, the high price of pollution abatement systems restricts the usage of coal to large consumers. A majority of the industrial, residential, and commercial sectors have switched to either natural gas or fuel oil. Domestic natural gas production in the United States, however, is falling, with the marginal supply picture making the system vulnerable to any disturbance such as supply interruptions (e.g., major storm, embargo), or weather extremes of heat or cold. Natural gas prices have consequently been very volatile over the past several years. Unless major changes are made in the supply situation, this trend will continue (Westervelt and Fournier 2005). Using petroleum as an energy source for buildings and heating plants is discouraged. Installations should investigate alternative fuels such as renewables that are less carbon-intensive and less likely to be disrupted. In central plants, dual fuel capability, where possible and economically feasible, should be provided to the maximum extent possible. Consideration should be given not only to conventional fuels (e.g., natural gas, propane, and liquefied natural gas), but also to proven renewable fuels (e.g., biogas, biofuels, wood, and refuse-derived fuels). Investigation of efficiency opportunities in renewable energy technologies — namely wind, biomass, geothermal, photovoltaics, and ground-source heat pumps — should be pursued when it is life-cycle cost effective (Fournier and Westervelt 2004).

Energy surety issues

Fournier and Westervelt (2004) define energy surety as "the proper combination of safety, reliability, and security." Energy surety is enhanced by anticipating and making plans to address the issues of potential disruptions, diversity of sources and delivery mechanisms, physical security, and the use of distributed energy resources such as renewable energy and on-site generation technology (Fournier and Westervelt 2004). According to Chapter 2, paragraph 2-1*d* of Army Regulation (AR) 420-49 *(Utility Systems)*, garrisons are to develop and implement an IUMP. The plan is to consider current Army utilities strategy by incorporating current utility practices; evaluate current and future garrison and tenant needs based on garrison mission, size, economic and environmental considerations; identify required resources; and outline a strategy to implement the selected program options. The IUMP is also to include utility system maps and sections on energy, solid waste management, corrosion control, and emergency response.

Candidate methodology

Introduction

The following section provides a candidate methodology for determining how utility system projects are chosen for the Utilities Modernization Program on an installation-by-installation basis. The process is divided into three major subtasks:

- Utilities Modernization Program planning;
- Installation Status Report (ISR) condition assessment; and
- Prioritization of utility systems.

Utilities Modernization Program planning

Modernization is a multi-discipline activity requiring 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 (Brewer et al. 1999).

The program planning process begins with the development of a well-defined Utilities Modernization Program plan. The plan will need to address business rules establishing which installations are eligible or not eligible to participate. Those installations that qualify under the Utilities Modernization Program will need to define their own site-specific Utilities Modernization plan, which will require the garrisons to define projects for central heating/air-conditioning and refrigeration plant and distribution systems and non-privatized utility systems (i.e., electric, natural gas, water, and wastewater) that have ISR ratings below satisfactory condition/quality levels. These utility systems will then be prioritized against established selection criteria. Once the list of utility systems has been formally prioritized and selected for the Army's POM budget cycle for FY08–13 under the Army Energy and Water Utilities Management Decision Package (MDEP), a Utilities Modernization Program Support Team will be established to accomplish technical and economic analyses and evaluations including, but not limited to, site visits and assessments at selected installations, reviews of fuel availabilities and environmental regulations, visual inspections of plants and distribution systems, energy supply options for modernizing utility systems (e.g., building a new plant, decentralization), design reviews, and project validation.

Installation Status Report condition assessment

To develop a Utilities Modernization project, a baseline condition assessment should be conducted. The ISR is a tool used by Army engineers and managers to plan funding for major Army programs. Condition assessments of each system and subsystem are evaluated on a C-rating (condition rating) scale, either by mission support level, quality level, quantity level, or overall readiness level. If the system or subsystem is in excellent condition, the system is given a C-1 (mission support/quantity/readiness) or Q-1 (quality) rating, while a system that is in failed or failing condition is given a C-4 or Q-4 rating. The choice of rating given by the installation determines the amount of dollars that will require a system or subsystem to be upgraded to satisfactory standards. In reality, the Army's POM budget is fiscally constrained; as a result, installations may not be able to receive the full amount of funding required to bring their utility systems to a C-1/Q-1 condition level. The color designations (OACSIM 2006) associated with C-ratings are as follows:

C-1/Q-1 = Green: Complies with standards; adequate system performance.

C-2/Q-2 = Amber: Does not fully meet standards; minimally adequate system performance.

C-3/Q-3 = Red: Does not meet standards; inadequate system performance.

C-4/Q-4 = Black: System performance in failed or failing condition.

Table 3 provides a mission support C-rating demographic of Operation and Maintenance (O&M)-funded Army- and Army Reserve-owned utility systems by C-rating level, as of 3rd Quarter, FY06.[1] The utility system inventory is based only on Army- and Army Reserve-owned systems located in the following IMCOM regions: Northeast, Northwest, Southeast, Southwest, and Pacific. No utility systems were counted for the IMCOM regions in Europe and Korea because these regions were outside the scope of this study.

[1] Information obtained using data, by installation, system, and C-rating, provided by Website (ISRWeb), Office of the Assistant Chief of Staff for Installation Management, http://isr.hqda.pentagon.mil.

Table 3. Mission support C-rating of Army- and Army Reserve-owned utility systems by rating level as of 3rd Quarter, FY06.

Utility Systems Under	No. of Heating / Air-Conditioning Systems	No. of Electrical Systems	No. of Natural Gas Distribution Systems	No. of Water Systems	No. of Sewer Systems	Total Number of Utility Systems	Percentage by Mission Status
C-1 mission status	18	28	24	24	21	115	51.57
C-2 mission status	13	16	5	19	14	67	30.04
C-3 mission status	12	4	4	5	8	33	14.80
C-4 mission status	3	1	3	0	1	8	3.59
Totals	46	49	36	48	44	223	100.00

From Table 3, it is seen that 48.43 percent of all O&M-funded Army- and Army Reserve-owned utility systems are less than C-1 mission support level status.

Prioritization of utility systems

The Utilities Modernization Program is focused on those utility systems that are either exempt from privatization or pending exemption from privatization. The listing of non-privatized, or Army-owned, utility systems is further shortened by identifying only those utility systems from Army installations funded by either O&M, Army (OMA) or O&M, Army Reserve (OMAR) appropriations. Each remaining non-privatized utility system and each remaining central heating/air-conditioning and refrigeration plant and distribution system will be evaluated based on the following criteria:

- ISR cost estimates for bringing systems to a C-1/Q-1 level rating
- Reported environmental (air or water) Notices of Violation (NOVs)
- Impact on mission dependency due to changes in mission requirements
- Energy savings, in terms of energy per square foot reduction and water consumption reduction.

Once the list of prioritized utility system projects is selected for Utilities Modernization programming under the FY08-13 POM cycle, Headquarters IMCOM (HQ IMCOM) will send out a data call. The data call would be similar to that done for Energy Conservation Investment Program (ECIP), but requiring a cover letter announcing the Utilities Modernization Program, with specific guidance on how installations can compete for modernization funds via submission of DD Form 1391 programming documents that provide information about their proposed modernization projects. The first year of the Utilities Modernization Program, however, will focus on a top-down driven approach based on ISR ratings of the candidate utility systems. Instances may occur where installations rate certain utility systems as "green," based on how the ISR questions are asked, but unique portions of those same systems may actually be rated either "amber" or "red." In that case, installations will need to explain why modernization funds are needed. HQ IMCOM will centrally manage the funds for the FY08-13 Utilities Modernization Program.

A way ahead

Candidate tasks to be accomplished by the Army for FY07-08 are listed below:

1. **Site visits and detailed assessments at selected installations by Utilities Modernization Support Team members:** Site visits and assessments for chosen installations will be necessary to validate the projects and to determine the most viable options available to improve each installation's energy supply situation where projects are underdeveloped. It should also be pointed out that not every project will warrant a site visit, depending upon the nature of its scope.
2. **Re-examination of criteria for non-privatized utility systems and central heating/air-conditioning and refrigeration plant and distribution systems:** Criteria established for prioritizing non-privatized utility systems and central heating/air-conditioning and refrigeration plant and distribution systems will need to be re-scrutinized due to changes in ISR ratings at the end of FY06, as well as unanticipated changes from non-privatized to privatized status for certain utility systems. The selection of utility system projects for the FY08-13 Utilities Modernization Program may be overcome by events (e.g., whether it is due to mission changes or political reasons).
3. **Detailed breakdown of costs to bring systems to less than a C-1 rating:** Part of the focus of the current study was to examine the prioritization criterion of ISR estimates to bring systems up to a C-1 rating. Because of POM funding constraints, the prioritization process will need to take into account ISR cost estimates to bring systems up from a C-3 or C-4 rating to a C-2 rating. This will also fulfill the guidance under DoD Instruction (DODI) 4170.11 (*Installation Energy Management*).
4. **Guidelines for preparation and generation of DD1391s:** Specific guidance should be established and refined as to how installations should properly prepare their DD1391 programming documents prior to DD1391 processor generation. Past DD1391 submissions under the FY98-02 Central Heating Plant Modernization Program were not approved because of incorrect work classification and/or project packaging. Individual maintenance and repair (M&R) projects that cost more than $3 million require

Headquarters, Department of the Army (HQDA) approval. In addition, M&R projects costing more than $7.5 million will require a 21-day Congressional notification before approval can be granted.

5. **Refinement of report discussions pertaining to proven, energy-efficient, and cost-effective technologies:** This report seeks to address those proven technologies that are energy-efficient, cost-effective, and relative only to systems external to the building. Further refinement will be required to examine some of these technologies in greater detail as to their applicability to modernization, along with others that were not previously identified in the report.
6. **Review of recapitalization projects:** The Utilities Modernization Support Team should review recapitalization projects that are completed or ongoing under privatization. Utilities privatization is considered the preferred method for modernizing and recapitalizing Army utility systems, allowing installations to focus on central defense missions and functions instead of being responsible for ownership of the utilities (Fournier and Westervelt 2004).

3 Prioritization of Utility Systems Exempt from Privatization or Pending Exemption from Privatization

Introduction

For those utility systems that are not subject to utilities privatization (otherwise called *legacy utility systems*), installations will need to establish and maintain, as a minimum, a C-2 condition level status (Fournier and Westervelt 2004). The systems that are not privatized must compete for limited resources under the DoD 67-year recapitalization rate. DODI 4170.11 (*Installation Energy Management*) directs DoD components to achieve a 67-year recapitalization and sustainment rate in which the readiness of existing facilities is restored to a C-2 status, on average, by the end of FY08.

AR 210-14 notes that C-ratings, also known as *condition ratings*, are the assessment of both the *quality* and *quantity* of available ISR reporting elements. A C-1 rating indicates that an ISR reporting element requires little immediate attention, while a C-4 rating highlights a true problem area for the installation. A C-5 rating indicates that an installation's status is being degraded due to an HQDA-directed action or program or is in a non-reportable status (e.g., Base Realignment and Closure [BRAC]).

The mission support C-ratings for ISR infrastructure roll-up, by category (e.g., water, sewer, etc.), are as follows:

- **C-1**, or Green: Mission C-Rating score < 1.5
- **C-2**, or Amber: Mission C-Rating score < 2.5
- **C-3**, or Red: Mission C-Rating score < 3.5
- **C-4**, or Black: Mission C-Rating score >=3.5

The quality C-ratings for ISR infrastructure, by category (e.g., water, sewer, etc.), are as follows:

- **Q-1**, or Green: Quality improvement costs <=10 percent of Plant Replacement Value (PRV)
- **Q-2**, or Amber: Quality improvement costs <=20 percent of PRV
- **Q-3**, or Red: Quality improvement costs <=40 percent of PRV

- **Q-4**, or Black: Quality improvement costs > 40 percent of PRV

Army- and Army Reserve-owned utility systems evaluated during the course of this study were the following:

- Central heating, air-conditioning, and refrigeration systems
- Electrical systems
- Natural gas systems
- Potable water systems
- Wastewater systems.

Central heating/air-conditioning and refrigeration systems are subject to Army-funded recapitalization improvements and are not part of the privatization program. The assumption on the remaining types of utility systems — electric, natural gas, water, and wastewater — is that privatization will result in upgrades of the systems to industry standards (i.e., equivalent to approximately C-1 condition level). The non-privatized systems are based on either those utility systems that are exempt from privatization or those systems that are pending exemption from privatization.

Listing of utility systems exempt from privatization or pending exemption from privatization

The ERDC-CERL PDT focused on those utility systems that are either exempt from privatization or pending exemption from privatization. Table 4 lists the 38 utility systems exempt from privatization under Defense Reform Initiative Directive (DRID) #49.

Table 4. Utility systems exempt from privatization under Defense Reform Initiative Directive #49.

IMCOM Region	Procurement Agency	Installation	Utility	Status
Northeast	Local DOC	Aberdeen PG (Edgewood Area) MD	Wastewater	Not Economical
Northeast	DESC	Fort Drum NY	Natural Gas	Not Economical (Post-RFP)
Northeast	Huntsville COE	West Point Military Reservation NY	Natural Gas	Not Economical (Post-RFP)
Northwest	Huntsville COE	Fort Carson CO	Wastewater	Not Economical (Post-RFP)
Northwest		Fort Lawton USAR Complex OK	Electric	No Interest
Northwest		Fort Lawton USAR Complex OK	Natural Gas	No Interest
Northwest		Fort Lawton USAR Complex OK	Potable Water	No Interest
Northwest		Fort Lawton USAR Complex OK	Wastewater	No Interest
Northwest		Fort McCoy WI	Potable Water	Not Economical (Pre-RFP)
Northwest		Fort McCoy WI	Wastewater	Not Economical (Pre-RFP)
Northwest		Stanley R. Mickelsen Safeguard Complex ND	Electric	Not Economical (Pre-RFP)

IMCOM Region	Procurement Agency	Installation	Utility	Status
Northwest		Stanley R. Mickelsen Safeguard Complex ND	Natural Gas	Not Economical (Pre-RFP)
Northwest		Stanley R. Mickelsen Safeguard Complex ND	Potable Water	Not Economical (Pre-RFP)
Northwest		Stanley R. Mickelsen Safeguard Complex ND	Wastewater	Not Economical (Pre-RFP)
Northwest	JMC	Tooele Army Depot UT	Electric	Not Economical (Post-RFP)
Northwest		Yakima Training Center WA	Electric	No Interest
Northwest		Yakima Training Center WA	Potable Water	No Interest
Northwest		Yakima Training Center WA	Wastewater	No Interest
Southeast	DESC	Fort Campbell KY	Electric	Not Economical (Post-RFP)
Southeast	Huntsville COE	Fort Gillem GA (on BRAC 2005 list)	Potable Water	Not Economical (Post-RFP)
Southeast	Huntsville COE	Fort Gillem GA (on BRAC 2005 list)	Wastewater	Not Economical (Post-RFP)
Southeast	Huntsville COE	Hunter Army Airfield GA	Potable Water	Not Economical (Post-RFP)
Southeast	Huntsville COE	Hunter Army Airfield GA	Wastewater	Not Economical (Post-RFP)
Southeast	Huntsville COE	Fort McPherson GA (on BRAC 2005 list)	Potable Water	Not Economical (Post-RFP)
Southeast	Huntsville COE	Fort McPherson GA (on BRAC 2005 list)	Wastewater	Not Economical (Post-RFP)
Southeast	Huntsville COE	Fort Stewart GA	Potable Water	Not Economical (Post-RFP)
Southeast	Huntsville COE	Fort Stewart GA	Wastewater	Not Economical (Post-RFP)
Southwest	DESC	Fort Huachuca AZ	Natural Gas	No Interest
Southwest	DESC	Fort Huachuca AZ	Potable Water	No Interest
Southwest	DESC	Fort Huachuca AZ	Wastewater	No Interest
Southwest		McAlester Army Ammunition Plant OK	Electric	Not Economical (Pre-RFP)
Southwest		Fort Sill OK	Electric	Not Economical (Pre-RFP)
Pacific		US Army Kwajalein Atoll	Electric	Not Economical (Pre-RFP)
Pacific		US Army Kwajalein Atoll	Potable Water	Not Economical (Pre-RFP)
Pacific		US Army Kwajalein Atoll	Wastewater	Not Economical (Pre-RFP)
Pacific		Wake Island	Electric	Not Economical (Pre-RFP)
Pacific		Wake Island	Potable Water	Not Economical (Pre-RFP)
Pacific		Wake Island	Wastewater	Not Economical (Pre-RFP)

Table 5 lists the 120 utility systems pending exemption from privatization.

Table 5. Utility systems pending exemption from privatization.

IMCOM Region	Procurement Agency	Installation	Utility	Status
Northeast	DESC	US Army Adelphi Laboratory Center MD	Electric	SSA[5] Decision Made
Northeast	DESC	US Army Adelphi Laboratory Center MD	Potable Water	SSA Decision Made
Northeast	DESC	US Army Adelphi Laboratory Center MD	Wastewater	SSA Decision Made
Northeast	DESC	Carlisle Barracks PA	Electric	SSA Decision Made
Northeast	DESC	Carlisle Barracks PA	Natural Gas	SSA Decision Made
Northeast	DESC	Carlisle Barracks PA	Potable Water	SSA Decision Made
Northeast	DESC	Carlisle Barracks PA	Wastewater	SSA Decision Made
Northeast	DESC	Fort Detrick MD	Electric	SSA Decision Made
Northeast	DESC	Fort Detrick MD	Potable Water	SSA Decision Made
Northeast	DESC	Fort Detrick MD	Wastewater	SSA Decision Made
Northeast	Huntsville COE	Fort Drum NY	Electric	SSA Decision Made
Northeast	Huntsville COE	Fort Drum NY	Potable Water	SSA Decision Made
Northeast	Huntsville COE	Fort Drum NY	Wastewater	SSA Decision Made
Northeast	DESC	Charles E. Kelly Support Center NJ	Electric	SSA Decision Made
Northeast	DESC	Charles E. Kelly Support Center NJ	Natural Gas	SSA Decision Made
Northeast	DESC	Charles E. Kelly Support Center NJ	Potable Water	SSA Decision Made
Northeast	DESC	Charles E. Kelly Support Center NJ	Wastewater	SSA Decision Made
Northeast	DESC	Fort Lee VA	Natural Gas	SSA Decision Made
Northeast	DESC	Fort McNair DC	Potable Water	SSA Decision Made
Northeast	DESC	Fort McNair DC	Wastewater	SSA Decision Made
Northeast	DESC	Fort Monmouth NJ (on BRAC 2005 list)	Potable Water	SSA Decision Made
Northeast	DESC	Fort Monmouth NJ (on BRAC 2005 list)	Wastewater	SSA Decision Made
Northeast	DESC	Fort Monmouth NJ (on BRAC 2005 list)	Electric	SSA Decision Made
Northeast	DESC	Fort Monroe VA	Natural Gas	SSA Decision Made
Northeast	DESC	Fort Myer VA	Potable Water	SSA Decision Made
Northeast	DESC	Fort Myer VA	Wastewater	SSA Decision Made
Northeast	DESC	Soldier Systems Center, Natick MA	Potable Water	SSA Decision Made
Northeast	DESC	Soldier Systems Center, Natick MA	Wastewater	SSA Decision Made

[5] SSA = Source Selection Authority, defined by Attachment D of OMB Circular No. A-76 (http://www.whitehouse.gov/omb/circulars/a076/a76_incl_tech_correction.html) as a competition official with decision-making authority who is responsible for source selection as required by Federal Acquisition Regulation Part 15.303 (and OMB Circular No. A-76.

IMCOM Region	Procurement Agency	Installation	Utility	Status
Northeast	DESC	Radford Army Ammunition Plant VA (GOCO)	Electric	SSA Decision Made
Northeast	DESC	Radford Army Ammunition Plant VA (GOCO)	Natural Gas	SSA Decision Made
Northeast	DESC	Radford Army Ammunition Plant VA (GOCO)	Potable Water	SSA Decision Made
Northeast	DESC	Radford Army Ammunition Plant VA (GOCO)	Wastewater	SSA Decision Made
Northeast	DESC	Tobyhanna Army Depot PA	Electric	SSA Decision Made
Northeast	DESC	Walter Reed Medical Center (on BRAC 2005 list)	Electric	SSA Decision Made
Northeast	DESC	Walter Reed Medical Center (on BRAC 2005 list)	Potable Water	SSA Decision Made
Northeast	DESC	Walter Reed Medical Center (on BRAC 2005 list)	Wastewater	SSA Decision Made
Northeast	TACOM	Watervliet Arsenal NY	Electric	SSA Decision Made
Northeast	TACOM	Watervliet Arsenal NY	Natural Gas	SSA Decision Made
Northeast	TACOM	Watervliet Arsenal NY	Potable Water	SSA Decision Made
Northeast	TACOM	Watervliet Arsenal NY	Wastewater	SSA Decision Made
Northeast	Huntsville COE	West Point Military Reservation NY	Electric	SSA Decision Made
Northwest	Huntsville COE	Fort Carson CO	Electric	SSA Decision Made
Northwest	Huntsville COE	Fort Carson CO	Natural Gas	SSA Decision Made
Northwest	Huntsville COE	Fort Carson CO	Potable Water	SSA Decision Made
Northwest	DESC	Fort Douglas AFRC Complex UT	Electric	SSA Decision Made
Northwest	DESC	Fort Douglas AFRC Complex UT	Natural Gas	SSA Decision Made
Northwest	DESC	Fort Douglas AFRC Complex UT	Potable Water	SSA Decision Made
Northwest	DESC	Fort Douglas AFRC Complex UT	Wastewater	SSA Decision Made
Northwest	ACA - NW	Dugway Proving Grounds UT	Electric	SSA Decision Made
Northwest	ACA - NW	Dugway Proving Grounds UT	Potable Water	SSA Decision Made
Northwest	ACA - NW	Dugway Proving Grounds UT	Wastewater	SSA Decision Made
Northwest	DESC	Iowa Army Ammunition Plant (GOCO)	Electric	SSA Decision Made
Northwest	DESC	Iowa Army Ammunition Plant (GOCO)	Natural Gas	SSA Decision Made
Northwest	DESC	Iowa Army Ammunition Plant (GOCO)	Potable Water	SSA Decision Made
Northwest	DESC	Iowa Army Ammunition Plant (GOCO)	Wastewater	SSA Decision Made
Northwest	DESC	Lake City Army Ammunition Plant MO (GOCO)	Electric	SSA Decision Made
Northwest	DESC	Lake City Army Ammunition Plant MO (GOCO)	Natural Gas	SSA Decision Made
Northwest	DESC	Lake City Army Ammunition Plant MO (GOCO)	Potable Water	SSA Decision Made
Northwest	DESC	Lake City Army Ammunition Plant MO (GOCO)	Wastewater	SSA Decision Made
Northwest	DESC	Fort Leavenworth KS	Natural Gas	SSA Decision Made

IMCOM Region	Procurement Agency	Installation	Utility	Status
Northwest	Local DOC	Lima Army Tank Plant OH	Electric	SSA Decision Made
Northwest	Local DOC	Lima Army Tank Plant OH	Natural Gas	SSA Decision Made
Northwest	Local DOC	Lima Army Tank Plant OH	Potable Water	SSA Decision Made
Northwest	Local DOC	Lima Army Tank Plant OH	Wastewater	SSA Decision Made
Northwest	Kansas City COE	Fort Riley KS	Potable Water	SSA Decision Made
Northwest	Kansas City COE	Fort Riley KS	Wastewater	SSA Decision Made
Northwest	Kansas City COE	Fort Riley KS	Natural Gas	SSA Decision Made
Northwest	Kansas City COE	Fort Riley KS	Electric	SSA Decision Made
Northwest	TACOM-Rock Island	Rock Island Arsenal IL	Electric	SSA Decision Made
Northwest	TACOM-Rock Island	Rock Island Arsenal IL	Natural Gas	SSA Decision Made
Northwest	TACOM	Rock Island Arsenal IL	Potable Water	SSA Decision Made
Northwest	TACOM	Rock Island Arsenal IL	Wastewater	SSA Decision Made
Northwest	DESC	US Army Garrison Selfridge MI	Electric	SSA Decision Made
Northwest	DESC	US Army Garrison Selfridge MI	Natural Gas	SSA Decision Made
Northwest	DESC	US Army Garrison Selfridge MI	Potable Water	SSA Decision Made
Northwest	DESC	US Army Garrison Selfridge MI	Wastewater	SSA Decision Made
Northwest	JMC	Tooele Army Depot UT	Potable Water	SSA Decision Made
Northwest	JMC	Tooele Army Depot UT	Wastewater	SSA Decision Made
Northwest	DESC	Vancouver Barracks WA	Electric	SSA Decision Made
Northwest	DESC	Vancouver Barracks WA	Potable Water	SSA Decision Made
Northwest	DESC	Vancouver Barracks WA	Wastewater	SSA Decision Made
Northwest	DESC	Detroit Arsenal MI	Electric	SSA Decision Made
Northwest	DESC	Detroit Arsenal MI	Potable Water	SSA Decision Made
Northwest	DESC	Detroit Arsenal MI	Wastewater	SSA Decision Made
Southeast	DESC	Anniston Army Depot AL	Natural Gas	SSA Decision Made
Southeast	DESC	Blue Grass Army Depot KY	Potable Water	SSA Decision Made
Southeast	DESC	Blue Grass Army Depot KY	Wastewater	SSA Decision Made
Southeast	DESC	Fort Gillem GA (on BRAC 2005 list)	Electric	SSA Decision Made
Southeast	DESC	Fort Gillem GA (on BRAC 2005 list)	Natural Gas	SSA Decision Made
Southeast	JMC	Holston Army Ammunition Plant TN (GOCO)	Electric	SSA Decision Made
Southeast	JMC	Holston Army Ammunition Plant TN (GOCO)	Natural Gas	SSA Decision Made
Southeast	JMC	Holston Army Ammunition Plant TN (GOCO)	Potable Water	SSA Decision Made
Southeast	JMC	Holston Army Ammunition Plant TN (GOCO)	Wastewater	SSA Decision Made

IMCOM Region	Procurement Agency	Installation	Utility	Status
Southeast	DESC	Fort Jackson SC	Natural Gas	SSA Decision Made
Southeast	DESC	Fort McPherson GA (on BRAC 2005 list)	Electric	SSA Decision Made
Southeast	DESC	Fort McPherson GA (on BRAC 2005 list)	Natural Gas	SSA Decision Made
Southeast	JMC	Milan Army Ammunition Plant TN (GOCO)	Electric	SSA Decision Made
Southeast	JMC	Milan Army Ammunition Plant TN (GOCO)	Potable Water	SSA Decision Made
Southeast	JMC	Milan Army Ammunition Plant TN (GOCO)	Wastewater	SSA Decision Made
Southeast	DESC	Military Ocean Terminal Sunny Point NC	Potable Water	SSA Decision Made
Southeast	DESC	Military Ocean Terminal Sunny Point NC	Wastewater	SSA Decision Made
Southeast	SMDC	Redstone Arsenal AL	Electric	SSA Decision Made
Southeast	SMDC	Redstone Arsenal AL	Natural Gas	SSA Decision Made
Southeast	SMDC	Redstone Arsenal AL	Potable Water	SSA Decision Made
Southeast	ACA - SE	Fort Knox KY	Natural Gas	SSA Decision Made
Southwest	DESC	Hawthorne Army Depot NV	Electric	SSA Decision Made
Southwest	DESC	Hawthorne Army Depot NV	Potable Water	SSA Decision Made
Southwest	DESC	Hawthorne Army Depot NV	Wastewater	SSA Decision Made
Southwest	DESC	Fort Hunter Liggett CA	Natural Gas	SSA Decision Made
Southwest	Huntsville COE	Fort Irwin CA	Natural Gas	SSA Decision Made
Southwest	DESC	Lone Star Army Ammunition Plant (on BRAC 2005 list)	Electric	SSA Decision Made
Southwest	DESC	Lone Star Army Ammunition Plant TX (on BRAC 2005 list)	Natural Gas	SSA Decision Made
Southwest	DESC	Lone Star Army Ammunition Plant TX (on BRAC 2005 list)	Potable Water	SSA Decision Made
Southwest	DESC	Lone Star Army Ammunition Plant TX (on BRAC 2005 list)	Wastewater	SSA Decision Made
Southwest	Local DOC	McAlester Army Ammunition Plant OK	Natural Gas	SSA Decision Made
Southwest	Local DOC	McAlester Army Ammunition Plant OK	Potable Water	SSA Decision Made
Southwest	Local DOC	McAlester Army Ammunition Plant OK	Wastewater	SSA Decision Made
Southwest	DESC	Red River Army Depot TX	Natural Gas	SSA Decision Made
Southwest	DESC	Sierra Army Depot CA	Potable Water	SSA Decision Made
Southwest	DESC	Sierra Army Depot CA	Wastewater	SSA Decision Made

Central heating plants are defined by Chapter 14 of Corps of Engineers *Technical Instruction 800-01* as facilities consisting of heat generators or multiple boilers, with the plants designed to be expandable when the facilities are expected to require future expansion. The central heating plant's capacity is defined by the number and size of units selected to efficiently handle both the maximum winter design load and the minimum summer load. If one of the units is off line, then the remaining unit or units would be required to carry not less than 65 percent or more than 75 percent of the maximum winter design load. The heating is required to be designed on the basis of the 97.5 percent winter design data for each location. Data are obtained online through the Air Force Combat Climatology Center's Strategic Climatic Information Service website at https://notus2.afccc.af.mil/SCIS/prodloc.asp (Select "Engineering Weather Data" under the "Product" pull-down menu, then click the "Submit" button). Tables 6 and 7 respectively list Army Active and Army Reserve-owned central heating plant systems, with capacities greater than or equal to 100 MBtu, that are subject to Army-funded recapitalization improvements. (The inventory was obtained based on real property data from Headquarters, Executive Information System [HQEIS].) Table 8 lists Army Active and Army Reserve-owned power plants, while Table 9 lists Army-owned air-conditioning and refrigeration plants.

Table 6. Inventory of Active Army-owned central heating plants, categorized by installation and fuel type.

IMCOM Region	Installation	Number of Active Army Central Heating Plants by Fuel Type							
		Coal-Fired	Dual Fuel-Fired	Gas-Fired	Gas-Generated	Oil-Fired	Steam-Generated	Geothermal-Fired	Total
Northeast	ABERDEEN PROVING GROUND MD	0	1	0	0	1	0	0	2
Northeast	PICATINNY ARSENAL NJ	0	1	0	0	0	0	0	1
Northeast	FORT BELVOIR VA	0	0	0	0	2	0	0	2
Northeast	FORT MEADE MD	0	0	0	0	0	1	0	1
Northeast	FORT HAMILTON NY	0	0	2	0	0	0	0	2
Northeast	WALTER REED ARMY MEDICAL CENTER DC	0	0	1	0	0	0	0	1
Northeast	WEST POINT MIL RESERVATION NY	0	0	1	0	0	0	0	1
Northwest	ROCK ISLAND ARSENAL IL	1	0	0	0	0	0	0	1
Northwest	SEBILLE MANOR FAMILY HOUSING MI	0	0	0	0	0	0	1	1
Northwest	US ARMY GARRISON SELFRIDGE MI	0	0	1	0	0	0	0	1
Northwest	FORT CARSON CO	0	0	1	0	0	0	0	1
Northwest	FORT LEONARD WOOD MO	0	0	1	0	2	0	0	3
Pacific	FORT RICHARDSON AK	0	0	1	0	0	0	0	1
Pacific	FORT WAINWRIGHT AK	1	0	0	0	0	0	0	1
Pacific	TORII STATION JAPAN	0	0	0	0	0	1	0	1
Southeast	ANNISTON ARMY DEPOT AL	0	1	0	0	0	0	0	1
Southeast	REDSTONE ARSENAL AL	0	1	0	0	1	0	0	2
Southeast	FORT BRAGG NC	0	0	1	0	1	0	0	2
Southeast	FORT STEWART GA	0	1	0	1	0	0	0	2
Southeast	FORT CAMPBELL KY	0	2	0	0	0	0	0	2
Southeast	HUNTER ARMY AIRFIELD GA	0	0	0	0	1	0	0	1
Southeast	FORT BENNING GA	0	1	0	0	0	0	0	1
Southeast	FORT GORDON GA	0	1	0	0	0	0	0	1
Southeast	FORT JACKSON SC	0	0	2	0	0	0	0	2

Southwest	RED RIVER ARMY DEPOT TX	1	0	0	0	0	0	0	1
Southwest	WHITE SANDS MISSILE RANGE NM	0	1	1	0	0	0	0	2
Southwest	FORT HOOD TX	0	0	0	1	0	0	0	1
Southwest	FORT SILL OK	0	0	1	0	1	0	0	2
Grand Totals		3	10	18	2	9	2	1	45

Table 7. Inventory of Army Reserve-owned central heating plants, categorized by installation and fuel type.

IMCOM Region	Installation	Number of Army Reserve Central Heating Plants by Fuel Type									
		Coal-Fired	Dual Fuel-Fired	Gas-Fired	Gas-Generated	Oil-Fired	Steam-Generated	Electric-Fired	Geothermal-Fired	Solar-Fired	Total
Northeast	FORT DIX NJ	0	0	0	0	2	0	0	0	0	2
Northwest	FORT MCCOY WI	0	0	1	0	0	0	0	0	0	1
Grand Totals		0	0	1	0	2	0	0	0	0	3

Table 8. Inventory of Active Army-owned and Army Reserve-owned power plants, categorized by installation and fuel type.

IMCOM Region	Installation	Number of Active Army and Army Reserve Power Plants by Fuel Type					
		Oil	PV	Gas	Coal	Hydroelectric	Total
Northeast	FORT EUSTIS VA	0	0	1	0	0	1
Northeast	PICATINNY ARSENAL NJ	0	0	0	1	0	1
Northwest	DUGWAY PROVING GROUND UT	2	1	0	0	0	3
Northwest	FORT MCCOY WI	0	0	0	1	0	1
Northwest	ROCK ISLAND ARSENAL IL	0	0	0	0	1	1
Pacific	FORT RICHARDSON AK	1	0	1	0	0	2
Pacific	FORT WAINWRIGHT AK	0	0	0	1	0	1
Southeast	REDSTONE ARSENAL AL	0	0	1	0	0	1
Southwest	HAWTHORNE ARMY DEPOT NV	1	0	0	0	0	1
Southwest	NTC AND FORT IRWIN, CA	0	0	1	0	0	1
Southwest	YUMA PROVING GROUND AZ	0	2	0	0	0	2
Grand Totals		4	3	4	3	1	15

Table 9. Inventory of Army-owned air-conditioning/refrigeration plants by installation.

IMCOM Region	Installation	Number of Air-Conditioning/ Refrigeration Plants
Northeast	ABERDEEN PROVING GROUND MD	1
Northeast	FORT EUSTIS VA	3
Northeast	FORT MEADE MD	1
Northeast	PICATINNY ARSENAL NJ	9
Northeast	SOLDIER SYSTEMS CENTER MA	3
Northeast	SSC HUDSON HOUSING NC	1
Northeast	USA ADELPHI LABORATORY CTR MD	2
Northeast	WEST POINT MIL RESERVATION NY	8
Northwest	DUGWAY PROVING GROUND UT	120
Northwest	FORT CARSON CO	1
Northwest	FORT LEAVENWORTH KS	3
Northwest	FORT LEONARD WOOD MO	7
Northwest	FORT RILEY KS	4
Northwest	ROCK ISLAND ARSENAL IL	3
Southeast	FORT BRAGG NC	10
Southeast	FORT CAMPBELL KY	12
Southeast	FORT GORDON GA	3
Southeast	FORT JACKSON SC	4
Southeast	FORT KNOX KY	1
Southeast	FORT STEWART GA	57
Southeast	HUNTER ARMY AIRFIELD GA	3
Southeast	REDSTONE ARSENAL AL	16
Southwest	FORT BLISS TX	3
Southwest	FORT HOOD TX	1
Southwest	FORT HUACHUCA AZ	3
Southwest	FORT POLK LA	2
Southwest	FORT SAM HOUSTON TX	13
Southwest	FORT SILL OK	12
Southwest	WHITE SANDS MISSILE RANGE NM	1
Southwest	YUMA PROVING GROUND AZ	124
Grand Totals		431

Table 10 provides the mission support and quality C-ratings, as of 3rd Quarter FY06,[6] for each Active Army- and Army Reserve-owned utility system exempt from privatization or pending exemption from privatization.

Table 10. Mission support and quality C-Ratings, as of Q3 FY06, for Army- and Army Reserve-owned utility systems exempt from privatization or pending exemption from privatization.

Installation Name	Utility Category	FY06, Qtr 3 Mission ISR C-Rating	FY06, Qtr 3 Quality ISR C-Rating
Aberdeen PG (Edgewood Area) MD	Heat/AC	C-3	Q-3
Aberdeen PG (Edgewood Area) MD	Wastewater	C-3	Q-2
Anniston Army Depot AL	Natural Gas	C-2	Q-1
Blue Grass Army Depot KY	Potable Water	C-1	Q-1
Blue Grass Army Depot KY	Wastewater	C-2	Q-2
Camp Zama Japan	Heat/AC	C-2	Q-2
Carlisle Barracks PA	Electric	C-1	Q-1
Carlisle Barracks PA	Natural Gas	C-1	Q-1
Carlisle Barracks PA	Potable Water	C-1	Q-1
Carlisle Barracks PA	Wastewater	C-1	Q-3
Charles E. Kelly Support Center PA	Electric	N/A	N/A
Charles E. Kelly Support Center PA	Natural Gas	N/A	N/A
Charles E. Kelly Support Center PA	Potable Water	N/A	N/A
Charles E. Kelly Support Center PA	Wastewater	N/A	N/A
Detroit Arsenal MI	Electric	C-1	Q-1
Detroit Arsenal MI	Potable Water	C-2	Q-2
Detroit Arsenal MI	Wastewater	C-2	Q-3
Dugway Proving Grounds UT	Electric	C-2	Q-1
Dugway Proving Grounds UT	Heat/AC	C-2	Q-1
Dugway Proving Grounds UT	Potable Water	C-1	Q-1
Dugway Proving Grounds UT	Wastewater	C-1	Q-1
Fort Belvoir VA	Heat/AC	C-1	Q-1
Fort Benning GA	Heat/AC	C-1	Q-1
Fort Bliss TX	Heat/AC	C-1	Q-1
Fort Bragg NC	Heat/AC	C-2	Q-2
Fort Campbell KY	Electric	C-3	Q-3
Fort Campbell KY	Heat/AC	C-3	Q-3
Fort Carson CO	Electric	C-2	Q-2
Fort Carson CO	Heat/AC	C-2	Q-2
Fort Carson CO	Natural Gas	C-2	Q-3
Fort Carson CO	Potable Water	C-2	Q-3
Fort Carson CO	Wastewater	C-2	Q-3
Fort Detrick MD	Electric	C-1	Q-1

6 ISR data for 1st Quarter FY06 obtained from OACSIM, *Installation Status Report Website* (ISRWeb), http://isr.hqda.pentagon.mil.

Installation Name	Utility Category	FY06, Qtr 3 Mission ISR C-Rating	FY06, Qtr 3 Quality ISR C-Rating
Fort Detrick MD	Potable Water	C-1	Q-1
Fort Detrick MD	Wastewater	C-1	Q-1
Fort Dix NJ	Heat/AC	C-3	Q-1
Fort Douglas AFRC Complex UT	Electric	N/A	N/A
Fort Douglas AFRC Complex UT	Natural Gas	N/A	N/A
Fort Douglas AFRC Complex UT	Potable Water	N/A	N/A
Fort Douglas AFRC Complex UT	Wastewater	N/A	N/A
Fort Drum NY	Electric	C-1	Q-1
Fort Drum NY	Natural Gas	C-1	Q-1
Fort Drum NY	Potable Water	C-2	Q-1
Fort Drum NY	Wastewater	C-3	Q-3
Fort Eustis VA	Heat/AC	C-3	Q-4
Fort Gillem GA (on BRAC 2005 list)	Electric	C-1	Q-1
Fort Gillem GA (on BRAC 2005 list)	Natural Gas	C-1	Q-1
Fort Gillem GA (on BRAC 2005 list)	Potable Water	C-2	Q-3
Fort Gillem GA (on BRAC 2005 list)	Wastewater	C-3	Q-3
Fort Gordon GA	Heat/AC	C-2	Q-1
Fort Greely AK	Heat/AC	C-2	Q-2
Fort Hood TX	Heat/AC	C-2	Q-1
Fort Huachuca AZ	Heat/AC	C-1	Q-1
Fort Huachuca AZ	Natural Gas	C-1	Q-1
Fort Huachuca AZ	Potable Water	C-1	Q-1
Fort Huachuca AZ	Wastewater	C-2	Q-1
Fort Hunter Liggett CA	Natural Gas	C-1	Q-1
Fort Irwin CA	Heat/AC	C-3	Q-3
Fort Irwin CA	Natural Gas	C-2	Q-3
Fort Jackson SC	Heat/AC	C-3	Q-3
Fort Jackson SC	Natural Gas	C-2	Q-1
Fort Knox KY	Heat/AC	C-1	Q-1
Fort Knox KY	Natural Gas	C-1	Q-1
Fort Lawton USAR Complex OK	Electric	N/A	N/A
Fort Lawton USAR Complex OK	Natural Gas	N/A	N/A
Fort Lawton USAR Complex OK	Potable Water	N/A	N/A
Fort Lawton USAR Complex OK	Wastewater	N/A	N/A
Fort Leavenworth KS	Heat/AC	C-1	Q-1
Fort Leavenworth KS	Natural Gas	C-1	Q-1
Fort Lee VA	Natural Gas	C-1	Q-1
Fort Leonard Wood MO	Heat/AC	C-1	Q-2
Fort Lewis WA	Heat/AC	C-3	Q-4
Fort McCoy WI	Heat/AC	N/A	N/A
Fort McCoy WI	Potable Water	C-2	Q-3
Fort McCoy WI	Wastewater	C-3	Q-3
Fort McNair DC	Potable Water	C-1	Q-1

Installation Name	Utility Category	FY06, Qtr 3 Mission ISR C-Rating	FY06, Qtr 3 Quality ISR C-Rating
Fort McNair DC	Wastewater	C-1	Q-1
Fort McPherson GA (on BRAC 2005 list)	Electric	N/A	N/A
Fort McPherson GA (on BRAC 2005 list)	Natural Gas	N/A	N/A
Fort McPherson GA (on BRAC 2005 list)	Potable Water	N/A	N/A
Fort McPherson GA (on BRAC 2005 list)	Wastewater	N/A	N/A
Fort Meade MD	Heat/AC	C-3	Q-4
Fort Monmouth NJ (on BRAC 2005 list)	Electric	N/A	N/A
Fort Monmouth NJ (on BRAC 2005 list)	Potable Water	N/A	N/A
Fort Monmouth NJ (on BRAC 2005 list)	Wastewater	N/A	N/A
Fort Monroe VA	Natural Gas	N/A	N/A
Fort Myer VA	Heat/AC	C-4	Q-4
Fort Myer VA	Potable Water	C-3	Q-4
Fort Myer VA	Wastewater	C-4	Q-4
Fort Polk LA	Heat/AC	C-3	Q-4
Fort Richardson AK	Heat/AC	C-3	Q-1
Fort Riley KS	Electric	C-1	Q-1
Fort Riley KS	Heat/AC	C-1	Q-1
Fort Riley KS	Natural Gas	C-2	Q-1
Fort Riley KS	Potable Water	C-1	Q-1
Fort Riley KS	Wastewater	C-1	Q-1
Fort Rucker AL	Heat/AC	C-1	Q-1
Fort Sam Houston TX	Heat/AC	C-1	Q-1
Fort Sill OK	Electric	C-1	Q-2
Fort Sill OK	Heat/AC	C-2	Q-1
Fort Stewart GA	Heat/AC	C-1	Q-1
Fort Stewart GA	Potable Water	C-2	Q-2
Fort Stewart GA	Wastewater	C-1	Q-1
Fort Wainwright AK	Heat/AC	C-3	Q-4
Holston Army Ammunition Plant TN (GOCO)	Electric	N/A	N/A
Holston Army Ammunition Plant TN (GOCO)	Natural Gas	N/A	N/A
Holston Army Ammunition Plant TN (GOCO)	Potable Water	N/A	N/A
Holston Army Ammunition Plant TN (GOCO)	Wastewater	N/A	N/A
Hunter Army Airfield GA	Heat/AC	C-1	Q-1
Hunter Army Airfield GA	Potable Water	C-1	Q-1
Hunter Army Airfield GA	Wastewater	C-1	Q-1
Iowa Army Ammunition Plant (GOCO)	Electric	N/A	N/A
Iowa Army Ammunition Plant (GOCO)	Natural Gas	N/A	N/A
Iowa Army Ammunition Plant (GOCO)	Potable Water	N/A	N/A
Iowa Army Ammunition Plant (GOCO)	Wastewater	N/A	N/A
Lake City Army Ammunition Plant MO (GOCO)	Electric	N/A	N/A
Lake City Army Ammunition Plant MO (GOCO)	Natural Gas	N/A	N/A
Lake City Army Ammunition Plant MO (GOCO)	Potable Water	N/A	N/A
Lake City Army Ammunition Plant MO (GOCO)	Wastewater	N/A	N/A

Installation Name	Utility Category	FY06, Qtr 3 Mission ISR C-Rating	FY06, Qtr 3 Quality ISR C-Rating
Lima Army Tank Plant OH (GOCO)	Electric	N/A	N/A
Lima Army Tank Plant OH (GOCO)	Natural Gas	N/A	N/A
Lima Army Tank Plant OH (GOCO)	Potable Water	N/A	N/A
Lima Army Tank Plant OH (GOCO)	Wastewater	N/A	N/A
Lone Star Army Ammunition Plant TX (on BRAC 2005 list)	Electric	N/A	N/A
Lone Star Army Ammunition Plant TX (on BRAC 2005 list)	Potable Water	N/A	N/A
Lone Star Army Ammunition Plant TX (on BRAC 2005 list)	Wastewater	N/A	N/A
Lone Star Army Ammunition Plant TX (on BRAC 2005 list)	Natural Gas	N/A	N/A
McAlester Army Ammunition Plant OK	Electric	C-1	Q-1
McAlester Army Ammunition Plant OK	Heat/AC	C-1	Q-1
McAlester Army Ammunition Plant OK	Natural Gas	C-1	Q-1
McAlester Army Ammunition Plant OK	Potable Water	C-1	Q-1
McAlester Army Ammunition Plant OK	Wastewater	C-1	Q-1
Milan Army Ammunition Plant TN (GOCO)	Electric	N/A	N/A
Milan Army Ammunition Plant TN (GOCO)	Potable Water	N/A	N/A
Milan Army Ammunition Plant TN (GOCO)	Wastewater	N/A	N/A
Military Ocean Terminal Sunny Point NC	Potable Water	C-1	Q-1
Military Ocean Terminal Sunny Point NC	Wastewater	C-1	Q-1
Picatinny Arsenal NJ	Heat/AC	C-4	Q-2
Radford Army Ammunition Plant VA (GOCO)	Electric	N/A	N/A
Radford Army Ammunition Plant VA (GOCO)	Natural Gas	N/A	N/A
Radford Army Ammunition Plant VA (GOCO)	Potable Water	N/A	N/A
Radford Army Ammunition Plant VA (GOCO)	Wastewater	N/A	N/A
Red River Army Depot TX	Natural Gas	C-3	Q-4
Redstone Arsenal AL	Electric	C-2	Q-2
Redstone Arsenal AL	Heat/AC	C-2	Q-2
Redstone Arsenal AL	Natural Gas	C-4	Q-4
Redstone Arsenal AL	Potable Water	C-2	Q-1
Rock Island Arsenal IL	Electric	C-2	Q-3
Rock Island Arsenal IL	Heat/AC	C-2	Q-3
Rock Island Arsenal IL	Natural Gas	C-1	Q-1
Rock Island Arsenal IL	Potable Water	C-1	Q-1
Rock Island Arsenal IL	Wastewater	C-1	Q-1
Schofield Bks Mil Reserve Hi	Heat/AC	C-1	Q-1
Sierra Army Depot CA	Potable Water	C-3	Q-3
Sierra Army Depot CA	Wastewater	C-3	Q-3
Soldier Systems Center, Natick MA	Heat/AC	C-2	Q-3
Soldier Systems Center, Natick MA	Potable Water	C-1	Q-1
Soldier Systems Center, Natick MA	Wastewater	C-1	Q-2
Stanley R. Mickelsen Safeguard Complex ND	Electric	N/A	N/A
Stanley R. Mickelsen Safeguard Complex ND	Natural Gas	N/A	N/A
Stanley R. Mickelsen Safeguard Complex ND	Potable Water	N/A	N/A
Stanley R. Mickelsen Safeguard Complex ND	Wastewater	N/A	N/A

Installation Name	Utility Category	FY06, Qtr 3 Mission ISR C-Rating	FY06, Qtr 3 Quality ISR C-Rating
Tobyhanna Army Depot PA	Electric	C-1	Q-1
Tooele Army Depot UT	Electric	C-2	Q-1
Tooele Army Depot UT	Potable Water	C-1	Q-1
Tooele Army Depot UT	Wastewater	C-2	Q-2
US Army Adelphi Laboratory Center MD	Electric	C-1	Q-1
US Army Adelphi Laboratory Center MD	Heat/AC	C-1	Q-1
US Army Adelphi Laboratory Center MD	Potable Water	C-1	Q-1
US Army Adelphi Laboratory Center MD	Wastewater	C-1	Q-1
US Army Garrison Selfridge MI	Electric	C-2	Q-3
US Army Garrison Selfridge MI	Natural Gas	C-1	Q-1
US Army Garrison Selfridge MI	Potable Water	C-2	Q-3
US Army Garrison Selfridge MI	Wastewater	C-2	Q-3
US Army Kwajalein Atoll	Electric	C-1	Q-2
US Army Kwajalein Atoll	Potable Water	C-2	Q-2
US Army Kwajalein Atoll	Wastewater	C-2	Q-2
Vancouver Barracks WA	Electric	N/A	N/A
Vancouver Barracks WA	Potable Water	N/A	N/A
Vancouver Barracks WA	Wastewater	N/A	N/A
Wake Island	Electric	N/A	N/A
Wake Island	Potable Water	N/A	N/A
Wake Island	Wastewater	N/A	N/A
Walter Reed Medical Center (on BRAC 2005 list)	Electric	C-2	Q-2
Walter Reed Medical Center (on BRAC 2005 list)	Potable Water	C-2	Q-2
Walter Reed Medical Center (on BRAC 2005 list)	Wastewater	C-2	Q-3
Watervliet Arsenal NY	Electric	C-1	Q-2
Watervliet Arsenal NY	Natural Gas	C-3	Q-4
Watervliet Arsenal NY	Potable Water	C-1	Q-1
Watervliet Arsenal NY	Wastewater	C-1	Q-1
West Point Military Reservation NY	Electric	C-1	Q-1
West Point Military Reservation NY	Heat/AC	C-2	Q-2
West Point Military Reservation NY	Natural Gas	C-1	Q-1
White Sands Missile Range NM	Heat/AC	C-3	Q-4
Yakima Training Center WA	Electric	C-1	Q-1
Yakima Training Center WA	Potable Water	C-1	Q-1
Yakima Training Center WA	Wastewater	C-1	Q-1
Yuma Proving Ground AZ	Heat/AC	C-1	Q-1

Methodology and criteria for prioritizing utility systems

Methodology

The ERDC-CERL PDT received from OACSIM an inventory of utility systems (by installation), organized according to the following categories:

- Utility systems that are privatized,
- Utility systems pending privatization contract award,
- Utility systems exempt from privatization under DRID #49,
- Utility systems pending exemption from privatization,
- Utility systems under negotiation status,
- Utility systems under an open, or RFP-issued, status, and
- Utility systems under a re-solicitation status.

At the request of OACSIM, the study's focus was centered on the following utility system categories from the aforementioned inventory that are not under privatization status:

- Utility systems exempt from privatization under DRID #49, and
- Utility systems pending exemption from privatization.

The non-privatized utility systems provided by OACSIM were compared with the utility systems (by installation) listed in the HQEIS database as of 3rd Quarter, FY06. The utility system data listed in HQEIS for each installation provided ownership codes (e.g., Army-owned, in-leased, privately owned, Residential Communities Initiative), funding categories, capacities, and ages associated with each system. The utility systems were then prioritized based on criteria discussed in the next section.

Criteria

The basis for prioritizing utility systems either exempt from privatization or pending exemption from privatization is the use of evaluation criteria. OACSIM provided the PDT with cost estimates (in thousands of dollars) for utility system upgrades, by each installation, to improve utility systems to C-1 condition based on their FY05 ISR ratings. Each cost estimate, with the exception of natural gas distribution systems, is broken down into the following ISR cost components by utility system type:

- Electrical utility system
    - Electric source

- Electric distribution
- Electric substations
- Heating/air-conditioning system
  - Heating/air-conditioning source
  - Heating/air-conditioning distribution
- Potable water system
  - Water source / treatment
  - Water storage
  - Water distribution
- Wastewater system
  - Wastewater treatment and disposal
  - Wastewater collection.

These cost estimates were one criterion for prioritizing utility systems, as suggested by OACSIM. Other suggested criteria for prioritizing utility systems include the following:

- Environmental NOVs
- Impact on mission dependency
- Energy savings (e.g., energy per square foot reduction, water consumption reduction).

Criteria considered but not used because of time constraints and the lack of available data were the following:

- Significant safety violations
- Hours of unscheduled outages.

Each criterion for each utility system was rated on the following scale, for consistency:

1 = No improvements needed

2 = Minor improvements needed

3 = Average improvements needed

4 = Above-average improvements needed

5 = Major improvements needed.

The primary criteria used for each utility system evaluated, along with applicable subcriteria, are the following:

- Overall quality improvement to C-1/Q-1 (green) rating
    - Quality improvement cost to C-1/Q-1 (from FY05 ISR)
    - Age
    - Capacity
    - Cost (from annual O&M or PRV costs)
- Impact on mission dependency
- Significant air or water quality violations reported
- Energy per square foot reduction, and
- Water consumption reduction.

Each of the aforementioned five primary criteria, for each utility system, is given an equal weighting factor, which is 1/5, or 0.20. The sum of the products for each individual criterion and its corresponding weighting factor results in an overall weighted rating score. The utility systems are then ranked 1 to n, with the overall weighted rating scores sorted from highest overall weighted rating score to lowest overall weighted rating score.

Complete details on the criteria and approach used in prioritizing the utility systems are documented in Appendix A. Sensitivity analyses were performed in validating the prioritization approach. Details and results of the sensitivity analyses are documented in Appendix B.

4 Candidate Life-Cycle Cost Analysis Tools to Aid in DD1391 Generation

Introduction

DD Form 1391 is the key method for installations to convey information about a proposed modernization project to the organizations responsible for approval and funding. The proposed project under the Utilities Modernization Program must be properly classified as a “Restoration & Modernization” project as opposed to a “Sustainment” project classification.

Sustainment deals with maintaining a facility in its current condition and includes regularly scheduled adjustments and inspections, preventative maintenance tasks, and emergency response for minor repairs. Sustainment also includes major repairs or replacement of facility components that are expected to occur periodically throughout the life cycle of facilities (e.g., roofs, heating/cooling systems).[7]

Restoration and *modernization* deal with improving facilities and are primarily accomplished with Military Construction (MILCON) funds but can be done with O&M funding depending upon the amount of new construction work in the project (current work classification and funding constraints still apply). Restoration improves existing facilities to current standards, while modernization adapts existing facilities to meet new standards.[8]

Table 11 provides examples of distinguishing Sustainment project classifications from Restoration and Modernization project classifications [ODUSD(I&E) 2006b].

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[7] Definition of “Sustainment” explained on “SRM Definition” website, OACSIM, http://www.hqda.army.mil/acsim/SRMdefinition.shtml.

[8] Definitions of “Restoration” and “Modernization” explained on “SRM Definition” website, OACSIM, http://www.hqda.army.mil/acsim/SRMdefinition.shtml.

Table 11. Examples of Restoration and Modernization projects versus Sustainment projects.

If a project is…	Example	Classification
1. Anticipated repair or replacement in the past that was deferred.	Exterior painting is peeling and has poor aesthetic appearance.	Sustainment
2. Repair or replacement required earlier than expected due to poor maintenance.	Replace poorly maintained roof which failed and caused collateral facility damage.	Restoration & Modernization
3. Repair or replacement due to poor maintenance but close to expected lifetime.	Replace roof that has been poorly maintained (no collateral damage).	Sustainment
4. Replacement of a system that has exceeded its expected lifetime.	Replace HVAC system that has exceeded expected life.	Sustainment
5. Replacement of a system that has exceeded its expected lifetime, but was extended by repair.	Runway pavement overlay.	Sustainment
6. Repair or replacement necessary because of natural catastrophe, war, or other circumstances beyond normal wear.	Replace officers' mess destroyed by fire.	Restoration & Modernization
7. Repair of one system because of the failure of another.	Repair interior damage from leaking roof.	Restoration & Modernization
8. Replacement of a system that has failed prematurely.	Replace HVAC system that was poorly designed and never worked properly.	Restoration & Modernization
9. Repair or replacement for aesthetic or historical preservation reasons.	Redecorate general officer quarters.	Restoration & Modernization
10. Upgrading a system for performance or energy conservation.	Replace existing lighting with more energy efficient system.	Restoration & Modernization
11. System replacement because of change in use.	Make a former commissary into an orchestra performance hall.	Restoration & Modernization
12. Renovation that will combine regular life-cycle maintenance and/or upgrade and/or change in use.	Renovate entire building and upgrade electrical system.	Split allocation

A Utilities Modernization Program Support Team, consisting of utility systems experts (composed of heating, cooling, water, wastewater, power plant and distribution system researchers and consultants) will perform site visits and detailed assessments at O&M-funded Army installations, beginning in FY07, to validate those projects that are in the design phase prior to approval and execution of the projects. The assessments will entail, but not be limited to, the following:

- Inventory and inspection of existing equipment (boilers, chillers, etc.)
- Distribution system inventory and inspection (electric, natural gas, heating/cooling, potable water, and wastewater). (*Note:* Aboveground piping is usually inspected visually, while buried piping may be assessed by infrared thermography, pressure testing, and/or excavation [VanBlaricum et al. 1999].)
- Verification of plant data (annual and peak loads, fuel use, boiler log data, water chemistry data, etc.)
- Inspection of corrosion control and cathodic protection systems.

Life-cycle cost analyses will be required for the following utility systems in preparation for DD1391 generation:

- Central heating/cooling plant and distribution systems
- Electrical systems
- Natural gas distribution systems
- Potable water systems
- Wastewater systems.

Central heating/cooling plant and distribution systems

A majority of the information in this section originated from Durbin et al. (1998).

Status quo evaluation

Based on the information obtained from the assessment:

1. Determine the useful life of the existing equipment, especially major components.
2. Develop repair estimates for system deficiencies.
3. Estimate required system life span.
4. Estimate the replacement cost for all systems, the useful life of which will expire during the life-cycle analysis time frame.
5. For the repaired current system, determine O&M costs and annual fuel consumption.

Economic evaluation of alternatives

Determine scenarios for possible central heating and cooling system options beginning with those with the greatest savings potential based on the utility costs. To reduce dependence on any particular fuel, consider a mix of energy sources based on the availability of the fuels. (For example, if #2 oil is used as a back-up to natural gas, be aware that oil prices and availability are closely coupled to natural gas price and availability.)

All possible energy sources should be identified and their current rate structures should be obtained from the local utilities. Natural gas, propane, coal, fuel oil, and electricity are available at most sites. Any applicable rebate programs or other incentives that could lower costs should be investigated. If possible, alternatives such as wind, solar, and geothermal energy should be considered. Use of waste energy (typically heat from engines or chillers) may also be a viable option (VanBlaricum et al. 1999).

Investigate systems that can be operated with reduced staff. Account for current and projected operators' skills necessary to operate and maintain potential options.

A listing of project alternatives for modernizing central heating and air-conditioning/refrigeration systems are discussed in greater detail in Appendix C. Industry standards related to electrical, natural gas, potable water, and wastewater systems are referenced in Appendixes D through G, respectively. Appendix H provides detailed descriptions of proven, energy-efficient, and cost-effective technologies.

The following list of actions should be considered when performing economic evaluations of the central heating/cooling plant and distribution system options.

1. Calculate equipment size and capital cost for each alternative. (For decentralized systems, realize that the sum of the required peak building loads will be much greater than the sum of the building loads used in a central system evaluation. The central systems can capitalize on load diversity. Additionally, for the decentralized option, some buildings will need to have redundant systems depending on the occupant's mission.)
2. Include building retrofit costs and any system retrofits, such as new gas lines, new HVAC equipment, and new electrical supply equipment.
3. Determine the annual O&M costs for each alternative using component efficiencies and maintenance requirements for the selected equipment.

4. Use building demand profiles to calculate annual energy consumption. Use conservative assumptions for energy efficiency in the first screening pass.
5. For the central heating plant options, use a program, such as HeatMap®, to calculate central energy plant and distribution system size and capital cost. HeatMap (http://www.energy.wsu.edu/software/heatmap.cfm) is a graphical thermal system (hot water, chilled water, and steam) economic feasibility analysis tool developed by Washington State University that can be used to help optimize the operation of installed thermal distribution systems.
6. Use metered data or thermal loads analysis where applicable for the consumer loads.
7. Check results against actual plant meter readings to verify models.
8. Make sure to include retrofit costs for both the buildings and the energy plants for different scenarios.
9. Account for the local environmental regulations for different locations, various fuel sources, and for different sizes of equipment.
10. Use a modular approach for central heating and cooling equipment sizing to increase reliability and to allow the base to better meet changing load requirements in the future.
11. Compare all reasonable options over the economic life of the equipment (usually 25 years). Sort the systems by their life-cycle cost, and then determine the sensitivity of the lowest cost systems to changes in fuel costs. Consider the complexity of the equipment and its maintenance requirements to select the scenario that will work most efficiently and reliably for the installation.

Life-cycle cost analysis tools

Among the commercial, off-the-shelf (COTS) software tools that can be used to calculate life-cycle costs for central heating/cooling plant and distribution system options are the following:

- **Basic Life-Cycle Cost (BLCC)**: This software was developed by the National Institute of Standards and Technology to provide an all-inclusive economic analysis of proposed capital investments that are expected to reduce long-term operating costs of buildings or buildings systems. BLCC calculates Lowest Life-Cycle Cost, Net Savings, Savings-to-Investment Ratio, Adjusted Internal Rate of Return, and Payback Period. Modules are also available for performing Federal Energy Management Program (FEMP) energy project analyses, Energy Savings Performance Contracts (ESPC) project analyses, OMB non-energy project analyses, and MILCON project analyses (e.g., ECIP project analyses). The BLCC software is updated annually to include the most up-to-date discount rates and fuel escalation values. A copy of the BLCC software can be obtained free-of-charge at http://www.eere.energy.gov/femp/information/download_blcc.cfm (registration is required before downloading the software).

- **Life Cycle Cost in Design (LCCID) for Windows**: This software was developed by ERDC-CERL and the University of Illinois Building Systems Laboratory to provide the user with a tool to perform an economic study, energy related or otherwise, that conforms to the economic criteria of the three primary services (Army, Air Force, and Navy). LCCID performs calculations conforming to Army, Air Force, and Navy criteria; standard Federal criteria; and ECIP criteria. Discount rates and fuel escalation values are provided annually for updates to the LCCID software. A copy of the LCCID software can be obtained at http://www.wbdg.org/tools/lccid.php.

Electrical systems

In the case of electrical energy source selection for *new* installations, the most economical electrical energy source will be selected based on the following criteria outlined in Section 1-8, paragraph *a*, of Army Technical Manual (TM) 5-811-1 (*Electrical Power Supply and Distribution*):

1. A life-cycle cost analysis is to be performed in accordance with methods discussed in Title 10, Part 436 of the Code of Federal Regulations (10 CFR 436) (http://www.wbdg.org/pdfs/10cfr436.pdf). The choices include supply from a private, government-owned generator plant, co-generation, solar energy, or combination of options.
2. The potential energy sources compared will include coal, oil, and purchased electricity (refuse-derived, geothermal or biomass-derived fuel will be considered, as applicable). Among the factors that will affect the choice of energy source are the following: availability, reliability, land right-of-way requirements, station or plant site needs, first costs for the installation including any pollution abatement requirements, and annual costs for energy and operating personnel wages.

In the case of electrical energy source selection for *existing* installations, the selection of an electrical energy source will be made when the existing source is inadequate to supply the requirements for the facility being added. An engineering study will need to be prepared according to the following guidance from Section 1-8, paragraph *b*, of Army TM 5-811-1:

1. Outside energy supplies will be evaluated based on the following:
   a. The reliability of the source;
   b. The cost of energy to the installation, based on projected demand and usage requirements;
   c. The ability of the supplier to serve the present and expected loads for the next 5 years; and
   d. System outages over the last 5 years, if available.
2. If no electrical master plan is currently in place, existing facilities will be evaluated by making a physical inspection of the existing facilities and accumulating the following data:
   a. Condition and characteristics of the existing off-site electrical energy sources;
   b. The number, condition, and characteristics of prime and auxiliary generating plants; and
   c. Load information.

No free COTS software tools are currently available that can be used for calculating life-cycle cost calculations for electrical system options.

Natural gas distribution systems

No free COTS software tools are currently available that can be used for calculating life-cycle cost calculations for natural gas distribution system options.

Potable water systems

Among the COTS software tools that can be used for calculating life-cycle costs for potable water system options are the following:

- **WATERGY**: This analysis tool, developed by the FEMP Office, is a spreadsheet model that uses water/energy relationship assumptions to analyze the potential of water savings and associated energy savings. WATERGY also enables the user to input utility data (energy and water cost and consumption data for the most recent 12 months) and facility data (number and kind of water consuming/moving devices and their water consumption and/or flow rates). WATERGY then estimates direct water, direct energy, and indirect energy annual savings, as well as total cost and payback times for the following potential conservation opportunities:
  - Installation of 1.6 gal/flush toilets and water conserving urinals;
  - Installation of automatic faucets;

  - Installation of faucet aerators;
  - Low-flow showerhead;
  - Boiler blowdown optimization;
  - Efficient dishwashers;
  - Efficient washing machines; and
  - Landscape irrigation optimization.

  A majority of the assumptions that WATERGY uses for energy/water calculations can be categorized by the following: (a) the heating values of fuels (e.g., the heating value of natural gas in British thermal units per cubit foot [Btu/cf]); (b) the efficiencies of energy and water consuming devices or processes (e.g., number of kilowatt hours consumed per gallon for electric hot water heaters, or number of kilowatt hours consumed per 1,000 gallons of treated waste water); (c) time-of-use for fixtures (e.g., number of minutes per use of infrared sensor faucets); and (d) percentage of hot water use in machines or fixtures (e.g., percentage of water usage that is hot water for a typical faucet). The WATERGY tool can be downloaded, free-of-charge, at the following website: http://www1.eere.energy.gov/femp/software/watergy3.xls.
- **BLCC:** More detail is explained in the section "Central Heating/Cooling Plant and Distribution Systems" under "Life-Cycle Cost Analysis Tools."

Wastewater systems

The life-cycle cost analysis for wastewater systems entails the evaluation of alternative wastewater processes and facility configurations using order-of-magnitude costs and a life-cycle cost evaluation including: capital costs, annual O&M costs estimated for the planning period, replacement costs during the planning period, salvage value and demolition or decommissioning costs at the end of the planning period, all in total present worth for each alternative.

5 A Candidate Utilities Modernization Plan for Fiscal Years 2008 to 2013

Summary

The *Army Energy Strategy for Installations*, signed by the Secretary of Army and the Army Chief of Staff on 8 July 2005, establishes the Army's energy goals from now to the year 2030 based on the following five major initiatives:

1. Eliminate energy waste in existing facilities;
2. Increase energy efficiency in new construction and renovations;
3. Reduce dependence on fossil fuels;
4. Conserve water resources; and
5. Improve energy security.

The Army is currently developing the *Army Energy and Water Campaign Plan for Installations* to provide a roadmap for achieving the Army Energy Strategy goals and initiatives. Utilities modernization is supported by Initiatives 1 through 5 under the *Army Energy and Water Campaign Plan for Installations*. *Modernization* is defined as the alteration of facilities solely to implement new or higher standards, to accommodate new functions, or to replace building components that exceed the overall service life of the facilities. Examples of modernization projects include the following: installing energy-efficient windows, upgrading electrical systems, upgrading for anti-terrorism and force protection, and upgrading to modern barracks standards. *Restoration* is defined as repair and replacement work to fix facilities damaged by inadequate sustainment, excessive age, natural disasters, fires, accidents, or other causes. Examples of restoration projects include the following: repair of structural failure, replacement of interior pipes, and repair of fire damage. *Sustainment*, as opposed to restoration and modernization, is defined as maintenance and repair activities necessary to keep an inventory of facilities in good working order. Sustainment also includes regularly scheduled maintenance as well as anticipated major repairs or replacement of components that occur periodically over the expected service life of the facilities. *Recapitalization*, on the other hand, includes both restoration and modernization of existing facilities, in which major renovation or reconstruction activities, including replacement of individual facilities, are necessary to keep an existing inventory of facilities modern and relevant in an environment of changing standards and missions. Recapitalization, however, does not include sustainment, acquisitions of new facilities, or the demolition of old facilities. The current DoD facilities recapitalization benchmark is 67 years.

In accordance with Chapter 2, Section 2-1 of AR 420-49, *Utility Systems*, environmental considerations, legal liabilities, manpower shortages, and reduced funding for operation and mission requirements can make it more advantageous for the Army to obtain utility services, when cost effective, from local, municipal, regional, and private service contractors.

Present status

The Army has extensive networks of utility systems at 109 installations in the United States, including Alaska and Hawaii. These networks provide water, wastewater treatment, solid waste management, electricity, natural gas, and heating/cooling. Utility services are provided by government-owned systems, purchases from local utilities, or a combination of both. The Army policy for utility systems, according to AR 420-49, is to obtain utility systems from local, municipal, or regional (public or private) authorities, rather than expand, build, or operate and maintain Army-owned utility systems.

Utilities modernization projects are based on utility systems from OMA-funded installations that are either exempt from privatization under DRID #49 or pending exemption from privatization. The PRV of these utility systems is estimated at $11 billion. The Utilities Modernization Program is supported by initiatives/actions under the *Army Energy and Water Campaign Plan for Installations*. Table 12 lists projected funding for Army projects [OMA, OMAR, and O&M, National Guard (OMNG)] under the POM FY08-13 cycle for Utilities Modernization.

Table 13 summarizes the Army-owned utility systems from OMA- and OMAR-funded installations in the United States (including Alaska and Hawaii).

Table 12. Funding for Utilities Modernization Program (POM 08-13).

Appropriation	FY08 ($K)	FY09 ($K)	FY10 ($K)	FY11 ($K)	FY12 ($K)	FY13 ($K)	Total ($K)
OMA	56,895	45,142	49,156	48,339	50,733	23,821	274,086
OMAR	2,393	1,898	2,067	2,033	2,134	1,002	11,527
OMNG	7,178	5,696	6,202	6,099	6,401	3,005	34,581
Less Electric Meter Installation (per Energy Policy Act of 2005 Guidance)	9,988	10,198	10,412	10,631	10,864	*	52,093
Less Design Funds (OMA)	3,000	3,000	3,000	3,000	3,000	3,000	18,000
Army Total	53,478	39,538	44,013	42,840	45,404	24,828	250,101
OMA Total Less Metering and Design	43,907	31,944	35,744	34,708	36,869	20,821	203,993
* FY12 is the final year for metering implementation.							

Table 13. Inventory of Army-owned utility systems in the United States.

Utility System	Quantity	Capacity	Plant Replacement Value, $B
Water Plants	490	194,790.4 KG	0.07
Chilled Water Distribution		147.8 miles	0.03
Potable Water Distribution		5,564.9 miles	1.02
Non-potable Water Distribution		266.0 miles	0.07
Wastewater Treatment Plants	189	192,760.3 KG	1.09
Wastewater Distribution		3,220.8 miles	0.73
Landfills	53	42,323,739.7 tons	1.96
Central Heating Plants	395	20,302.9 MBtu	0.22
AC/Refrigeration Plants	431	145,693.8 tons	0.51
Gas Generation Plants	4	314.3 MBtu	0.001
Heat Distribution		1,071.6 miles	1.88
Electrical Power Source	15	67,399.0 KV	0.11
Electrical Standby Power	503	170,352.5 KV	0.05
Exterior Lighting		3,156.7 miles	0.27
Electrical Substations	525	4,815,596.2 KV	0.45
Electrical Power Lines		10,279.3 miles	2.14
Natural Gas Distribution		1,489.6 miles	0.49
Total			11.09

The Army has numerous programs to provide training and technical guidance documents to installations in O&M and modernization of the utility systems. In addition to appropriated funds (i.e., OMA, OMAR, and OMNG), other sources of funding for energy projects include the following:

- *Enhanced Use Leasing*, which enables the Army to out-lease available non-excess real property to the private sector in return for cash and in-kind consideration;
- *Energy Conservation Investment Program (ECIP)*, which is a DoD program designed to improve the energy efficiency of DoD facilities while reducing associated utility energy and non-energy related costs;
- *Energy Savings Performance Contracts (ESPCs)*, which are partnerships with private sector companies known as energy service companies (ESCOs) that arrange financing to develop and install energy/water conservation and renewable energy projects, guaranteeing anticipated energy cost savings — paid back to the ESCO — to be generated by the project over the contract's life (up to 25 years); and
- *Utility Energy Savings Contracts (UESCs)*, which are similar to ESPCs, except that projects are financed and implemented through utility companies, with the contract's life up to 10 years.

The Utilities Modernization Program is included in the Army Energy and Water Utilities MDEP, which has to be defended each FY to ensure that the following requirements are met during FY08 and the out-years:

- Metering of facilities, as required by the *Energy Policy Act of 2005* (EPAct05);
- Support of the Army Campaign Plan, Army Modular Forces (AMF), and the Global Defense Posturing Realignment (GDPR) as "must-fund" obligations for critical mission requirements;
- Resolution of environmental NOVs to meet new utility plant requirements standards (i.e., NESHAP); and
- Elimination of waste and diversion of resources to pay increased bills for inefficient utility plants/systems.

Utilities Modernization Program eligibility

The Utilities Modernization Program is a program eligible to Army installations overseen by the IMCOM, Army Reserves, and National Guard, with OMA-, OMAR-, and OMNG-appropriated funding. Army installations *not* eligible for the Utilities Modernization Program are the following:

- DoD-funded installations;
- Government-Owned/Contractor-Operated (GOCO) installations, primarily Army Materiel Command (AMC) installations, that operate under Army Working Capital Funds (AWCF), and Procurement Ammunition Army (PAA) installations;
- Army mission-funded installations, including Space and Missile Defense Command (SMDC) installations and Surface Deployment and Distribution Command (SDDC) installations;
- Medical Command installations that operate under TRICARE Management Activity (TMA) funds;
- Defense Logistics Agency (DLA) installations;
- Army National Guard (ARNG) or US Army Reserve (USAR) Centers located on DoD-funded, AWCF, PAA, Army mission-funded, TMA, or DLA installations;
- ARNG maintenance facilities located on DoD-funded, AWCF, PAA, Army mission-funded, TMA, or DLA installations;
- Excess/inactive installations; and
- Installations closed or closing under BRAC.

The candidate utility system projects that qualify under the Utilities Modernization Program will be selected for each FY based on the following criteria for prioritizing utility systems:

1. Overall quality improvement to C-1/Q-1 (green) ISR rating
2. Impact on mission dependency (military/civilian population increase/decrease based on BRAC, AMF, and GDPR)
3. Significant air or water quality violations reported
4. Energy per square foot reduction
5. Water consumption reduction.

Project planning process

Each installation eligible for the Utilities Modernization Program will need to define their own utilities management plan, requiring the garrisons to define projects with utility commodities (i.e., electric, natural gas, water, wastewater, heating, and cooling) that have ISR quality ratings below C-1/Q-1 (green). The installations will need to engage with their Master Planning personnel to establish a plan/roadmap for future projects based on those utility systems that need their ISR quality ratings brought up to "green."

Project alternatives include the following:

- Upgrades and refurbishments of existing central heating and distribution systems
- Full or partial decentralization of central heating and/or cooling systems
- Conversion from steam to hot water in the distribution system
- New central chilled water systems or additions to existing systems
- Cogeneration (combined heat and power) systems
- Trigeneration (combined cooling, heat, and power) systems
- Thermal storage cooling systems for demand-side management.

Each installation will need to develop technically sound DD1391s for their future utility system projects in order to satisfy the required needs of the installation. IMCOM will provide to the garrisons an official tasker requesting installations to submit to IMCOM within 6 months their DD1391s that clearly address the modernization solutions to their ISR problems.

Each DD1391 should contain the following information:

- Project description
- Narrative of requirement
- Current situation
- Impact if not provided
- Estimated starting date of construction
- Estimated midpoint of construction
- Estimated completion date of construction
- Cost data
- Analysis of deficiencies
- Criteria for proposed construction
- Disposal/demolition facility list (if applicable)
- Narrative of environmental documentation
- Summary of environmental consequences.

Design funds will be released by IMCOM to the installation only after IMCOM approves the DD1391s.

Identification of proven, energy-efficient, cost-effective technologies

The Utilities Modernization Program will focus on systems *external* to the building and not on individual systems within buildings. The technologies that would best apply to the appropriate utility systems must be proven, energy-efficient, and cost-effective. Among these technologies are the following:

- Ground-source heat pumps
- Distributed generation
- Renewable energy technologies.

Execution plan

Complete modernization requires a major effort by the Army beyond current resource levels. The key elements are:

- Development of criteria for prioritizing utility systems.
- Development of site-specific utilities modernization plans and DD1391s for future utility system projects by installations.
- Establishment of a Utilities Modernization Program Support Team to accomplish evaluations to establish the most practical, economic, and efficient methods to modernize/recapitalize Army utility systems that are either exempt from privatization or pending exemption from privatization.

Future

The *Army Energy and Water Campaign Plan for Installations* states that the primary issues affecting the supply of energy and water resources are the following: *availability*, *affordability*, *sustainability*, and *security*. Utilities modernization is integrated into the following five initiatives under the *Army Energy and Water Campaign Plan for Installations*:

- Initiative #1: Eliminate energy inefficiencies that waste natural and financial resources, and do so in a manner that does not adversely impact comfort and quality of the facilities in which Soldiers, families, civilians, and contractors work and live.

- Initiative #2: Increase the use of energy technologies in construction and major renovation projects that provide the greatest cost-effectiveness, energy efficiency, and support to the Army's environmental objectives.
- Initiative #3: Reduce the dependency on fossil fuels by increasing the use of clean, renewable energy, reducing waste, increasing efficiencies, and improving environmental benefits.
- Initiative #4: Reduce water use to conserve water resources for drinking and domestic purposes.
- Initiative #5: Improve the security and reliability of our energy and water systems in order to provide dependable utility service.

Actions must be taken sooner rather than later to achieve the goals set forth in the *Army Energy and Water Campaign Plan for Installations* in order to establish technologically efficient, environmentally friendly, and cost-effective energy and water requirements in the future.

6 Recommendations

Based on the efforts accomplished in FY06, the following tasks are proposed during the FY07 timeframe:

1. Site visits and detailed assessments by Utilities Modernization Program Support Team members to validate projects and to determine the most viable options available to improve each installation's energy supply situation.
2. Re-examination of criteria established for non-privatized utility systems and central heating/air-conditioning and refrigeration supply and distribution systems due to changes in the ISR ratings at the end of FY06.
3. Re-examination of the ISR cost estimates to include detailed breakdowns of costs for bringing up those utility systems from a C-3 or C-4 rating to a C-2 rating in accordance with DODI 4170.11.
4. Establishment and refinement of guidance explaining how installations should properly prepare their DD1391 programming documents prior to DD1391 processor generation.
5. Refinement of proven, energy-efficient, and cost-effective technologies applicable to modernization.
6. Review of recapitalization projects that are completed or ongoing under privatization.

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Appendix A: Criteria for Prioritization of Utility Systems

Overall quality improvement to C-1/Q-1 (green) rating

Overall quality improvement rankings were determined using the following subcriteria:

- Quality Improvement Cost to C-1/Q-1: Quality improvement costs to C-1/Q-1 (mission/quality), or "green" rating were obtained using data from ISRWeb (http://isr.hqda.pentagon.mil/) as of fourth quarter, Fiscal Year 2005 (FY05). Operations and Maintenance, Army Maintenance and Repair projects more than $3 million require approval by the Department of the Army). Each cost was rated from 1 to 5 (**1** = 0 to $500K; **2** = $501K to $1,000K; **3** = $1,001K to $1,500K; **4** = $1,501K to $2,000K; **5** = $2,001K or greater).
- Age: The age of the plant or utility system for each installation was determined from HQEIS real property data. Each plant or utility system was rated from 1 to 5 (**1 =** 0 to 10 years; **2 =** 11 to 20 years; **3 =** 21 to 30 years; **4 =** 31 to 40 years; **5 =** 41 years or greater).
- Capacity: The capacity is defined as the total requirements of each plant or utility system (e.g., million Btu [MB] for heating plants, tons [TN] for cooling plants, kilovolts [KV] for electric systems, linear feet [LF] for natural gas distribution systems, and kilograms [KG] for water and wastewater systems). Depending on the utility system type, the capacity is then divided by the appropriate average requirement per KSF of that system type and then rated from 1 to 5 (**1 =** <80% of average; **2 =** 81% to 100% of average; **3 =** 101% to 110%; **4 =** 111% to 120% of average; **5 =** > 120% of average).
- Cost: The cost can come from either the annual operations and maintenance (O&M) cost or Plant Replacement Value of the utility system or plant. Depending on the utility system type, the cost is then divided by the capacity (defined by the description above), divided by the appropriate average cost per unit of capacity, then rated from 1 to 5 (**1 =** Very Low, or < 80% of Average Cost per Unit of Capacity; **2 =** Low, or 81% to 100%; **3 =** Average, or 101% to 110%; **4 =** Above Average, or 110% to 120%; and **5 =** Very High, or > 120%).

Each subcriterion is given an equal weighting factor, which is 1/4, or 0.25. The overall weighted rating for the quality improvement criteria is then evaluated as follows:

Quality improvement weighted rating = [Quality improvement cost * Quality improvement cost weighting factor] + [Age rating * Age weighting factor] + [Capacity rating * Capacity weighting factor] + [Cost * Cost weighting factor]

Impact on mission dependency

Mission dependency data, based on total net change (positive or negative) in both military and civilian population due to troop stationing (Army Modular Force and Global Defense Posturing Realignment) and Base Re-alignment and Closure 2005 actions/recommendations, was obtained from the Defense Base Closure and Realignment Commission website (http://www.brac.gov) and the Force Management System Web Site (https://webtaads.belvoir.army.mil/). The total net change is rated from 1 to 5 (**1** = 199 and below; **2** = 200 to 399; **3** = 400 to 599; **4** = 600 to 799; **5** = 800 and greater).

Significant air or water quality violations reported

Data for environmental violations reported for each utility system by in-stallation were obtained using these U.S. Environmental Protection Agency (USEPA) databases: Enforcement and Compliance History Online for air quality violations (http://www.epa.gov/echo/compliance_report_air.html) and wastewater violations (http://www.epa.gov/echo/compliance_report_water.html); and the Safe Drinking Water Information System for water quality violations (http://www.epa.gov/enviro/html/sdwis/sdwis_query.html). The number of violations is rated from 1 to 5 (**1** = 0 to 2 violations; **2** = 3 to 5 violations; **3** = 6 to 8 vio-lations; **4** = 9 to 11 violations; **5** = 12 violations and greater).

Energy per square foot reduction

Title I, Section 102 of the *Energy Policy Act of 2005* (EPAct05) states that the energy reduction goal for Federal energy buildings is 2% reduction of energy consumption per square foot (KBtu/SF) by FY06, compared to FY03 levels, with the ultimate goal of 20% reduction of KBtu/SF by FY15. The average reduction between FY03 and FY06 would calculate to be 2% divided by 3 years, or 0.67%/yr. Therefore, the energy reduction goal by FY05 would be 2 * 0.67%, or 1.33%. Data for energy per square foot reduction, as a percentage of KBtu/SF reduction between FY03 and FY05 levels (with FY03 levels as the baseline because of the EPAct05), was obtained using each installation's energy consumption and square footage data from the Army Energy and Water Reporting System (AEWRS) (https://aewrs.hqda.pentagon.mil/aewrs/). The percentage of energy per square foot reduction is rated from 1 to 5 (**1** = 1.33% and greater; **2** = 0.33% to 1.329%; **3** = -0.67% to 0.329%; **4** = -1.67% to -0.671%; **5** = -1.671% and below).

Water consumption reduction

Water consumption reduction, as a percentage of water consumption reduction between FY02 and FY05 levels, was determined for each installation using water consumption data obtained from AEWRS. (*Note*: This criterion applies only to potable water systems.) The percentage of water consumption reduction is rated from 1 to 5 (**1** = 3% and greater; **2** = 2.5% to 2.99%; **3** = 2% to 2.49%; **4** = 1.5% to 1.99%; **5** = 1.49% and below).

Weighted rating as basis for prioritizing utility systems

All of the above criteria are given an equal weighting factor, which is 1/5, or 0.200 (all 5 weighting factors, when summed up, should equal to 1). For each installation's utility system, each criterion is rated on a scale of 1 to 5 (with 1 being the best and 5 the worst), and the rating scale is defined as follows:

1 = No improvements needed

2 = Minor improvements needed

3 = Average improvements needed

4 = Above-average improvements needed

5 = Major improvements needed

The overall weighted rating would then be calculated as follows:

Overall weighted rating =

Quality improvement weighted rating (evaluated in formula earlier discussed) + [Mission dependency rating * Mission dependency weighting factor] + [Energy reduction rating * Energy reduction weighting factor] + [Water consumption reduction rating * Water consumption reduction weighting factor] + [Environmental violation rating * Environmental violation weighting factor]

The utility systems are then ranked 1 to n, with the overall weighted ratings sorted in descending order (highest weighted rating value to lowest weighted rating value).

Results based on prioritization criteria

Based on the prioritization criteria established for utility systems, the results of the utility system rankings, as sorted by highest to lowest weighted rating value, are shown below in Table A1. Regional offices listed in column two are Northeast Region (NERO), Northwest Region (NWRO), Pacific Region (PARO), Southeast Region (SERO), and Southwest Region (SWRO).

Table A1. Results of prioritization analysis of utility systems.

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT DRUM NY	NERO	Water	1.00	0.80	0.20	0.20	0.80	3.00	1
FORT GEORGE G MEADE MD	NERO	Heat/AC	1.00	0.80	1.00	0.00	0.20	3.00	1
FORT BRAGG NC	SERO	Heat/AC	1.00	0.66	1.00	0.00	0.20	2.86	3
FORT BELVOIR VA	NERO	Heat/AC	1.00	0.56	1.00	0.00	0.20	2.76	4
FORT LEE VA	NERO	Natural Gas	1.00	0.70	1.00	0.00	0.00	2.70	5
REDSTONE ARSENAL AL	SERO	Heat/AC	0.80	0.86	1.00	0.00	0.00	2.66	6
FORT STEWART GA	SERO	Water	1.00	0.60	0.20	0.20	0.60	2.60	7
FORT HOOD TX	SWRO	Heat/AC	1.00	0.40	1.00	0.00	0.00	2.40	8
FORT RILEY KS	NWRO	Water	1.00	0.60	0.20	0.20	0.40	2.40	8
FORT SILL OK	SWRO	Heat/AC	1.00	0.76	0.60	0.00	0.00	2.36	10
ROCK ISLAND ARSENAL IL	NWRO	Water	0.00	0.66	1.00	0.40	0.20	2.26	11
FORT SILL OK	SWRO	Electric	1.00	0.60	0.60	0.00	0.00	2.20	12
FORT DIX NJ	NERO	Heat/AC	0.40	0.76	1.00	0.00	0.00	2.16	13
FORT LEWIS WA	NWRO	Heat/AC	1.00	0.56	0.20	0.00	0.40	2.16	13
FORT SAM HOUSTON TX	SWRO	Heat/AC	1.00	0.56	0.60	0.00	0.00	2.16	13
FORT LEAVENWORTH KS	NWRO	Natural Gas	0.40	0.70	1.00	0.00	0.00	2.10	16
ROCK ISLAND ARSENAL IL	NWRO	Heat/AC	0.00	0.90	1.00	0.00	0.20	2.10	16
FORT BENNING GA	SERO	Heat/AC	1.00	0.66	0.20	0.00	0.20	2.06	18
FORT JACKSON SC	SERO	Heat/AC	0.80	0.60	0.40	0.00	0.20	2.00	19
DUGWAY PROVING GROUND UT	NWRO	Electric	0.00	1.00	1.00	0.00	0.00	2.00	20
DUGWAY PROVING GROUND UT	NWRO	Water	0.00	0.80	1.00	0.20	0.00	2.00	20

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT CARSON CO	NWRO	Wastewater	1.00	0.80	0.20	0.00	0.00	2.00	20
FORT CARSON CO	NWRO	Water	1.00	0.60	0.20	0.20	0.00	2.00	20
FORT DRUM NY	NERO	Electric	1.00	0.80	0.20	0.00	0.00	2.00	20
FORT MYER VA	NERO	Water	0.00	0.80	0.20	1.00	0.00	2.00	20
FORT WAINWRIGHT AK	PARO	Heat/AC	1.00	1.00	0.00	0.00	0.00	2.00	20
FORT CAMPBELL KY	SERO	Heat/AC	1.00	0.80	0.20	0.00	0.00	2.00	20
NTC AND FORT IRWIN CA	SWRO	Natural Gas	0.00	1.00	1.00	0.00	0.00	2.00	20
PICATINNY ARSENAL NJ	NERO	Heat/AC	0.80	1.00	0.20	0.00	0.00	2.00	20
FORT CARSON CO	NWRO	Heat/AC	1.00	0.76	0.20	0.00	0.00	1.96	30
FORT LEAVENWORTH KS	NWRO	Heat/AC	0.40	0.56	1.00	0.00	0.00	1.96	31
ABERDEEN PROVING GROUND MD	NERO	Heat/AC	1.00	0.70	0.20	0.00	0.00	1.90	32
WHITE SANDS MISSLE RANGE NM	SWRO	Heat/AC	0.00	0.90	1.00	0.00	0.00	1.90	33
FORT STEWART GA	SERO	Wastewater	1.00	0.66	0.20	0.00	0.00	1.86	34
DUGWAY PROVING GROUND UT	NWRO	Heat/AC	0.00	0.86	1.00	0.00	0.00	1.86	35
FORT RUCKER AL	SERO	Heat/AC	1.00	0.46	0.20	0.00	0.20	1.86	35
CARLISLE BARRACKS PA	NERO	Water	0.00	0.60	0.20	1.00	0.00	1.80	37
FORT CARSON CO	NWRO	Electric	1.00	0.60	0.20	0.00	0.00	1.80	37
FORT LESLEY J MCNAIR VA	NERO	Water	0.00	0.60	0.20	1.00	0.00	1.80	37
ABERDEEN PROVING GROUND MD	NERO	Wastewater	1.00	0.56	0.20	0.00	0.00	1.76	40
FORT CARSON CO	NWRO	Natural Gas	1.00	0.56	0.20	0.00	0.00	1.76	40
FORT DRUM NY	NERO	Natural Gas	1.00	0.56	0.20	0.00	0.00	1.76	40
FORT HUNTER LIGGETT CA	SWRO	Natural Gas	0.20	0.56	1.00	0.00	0.00	1.76	40
FORT MCCOY WI	NWRO	Water	0.00	0.36	0.20	1.00	0.20	1.76	40
FORT RILEY KS	NWRO	Heat/AC	1.00	0.56	0.20	0.00	0.00	1.76	40
FORT STEWART GA	SERO	Heat/AC	1.00	0.50	0.20	0.00	0.00	1.70	46
FT CAMPBELL KY	SERO	Electric	1.00	0.50	0.20	0.00	0.00	1.70	46
NTC AND FORT IRWIN CA	SWRO	Heat/AC	0.00	0.66	1.00	0.00	0.00	1.66	48
FORT BLISS TX	SWRO	Heat/AC	1.00	0.46	0.20	0.00	0.00	1.66	49
FORT RILEY KS	NWRO	Natural Gas	1.00	0.46	0.20	0.00	0.00	1.66	49
FORT RILEY KS	NWRO	Wastewater	1.00	0.46	0.20	0.00	0.00	1.66	49
DUGWAY PROVING GROUND UT	NWRO	Wastewater	0.00	0.60	1.00	0.00	0.00	1.60	52
FORT JACKSON SC	SERO	Natural Gas	0.80	0.40	0.40	0.00	0.00	1.60	52
ROCK ISLAND ARSENAL IL	NWRO	Electric	0.00	0.60	1.00	0.00	0.00	1.60	52
SCHOFIELD BKS MIL RESERVE HI	PARO	Heat/AC	1.00	0.60	0.00	0.00	0.00	1.60	52
SOLDIER SYSTEMS CENTER MA	NERO	Water	0.00	0.40	0.20	1.00	0.00	1.60	52
WEST POINT MIL RESERVATION NY	NERO	Heat/AC	0.40	0.80	0.20	0.00	0.20	1.60	52
YUMA PROVING GROUND AZ	SWRO	Heat/AC	0.00	0.60	1.00	0.00	0.00	1.60	52
FORT RICHARDSON AK	PARO	Heat/AC	0.40	1.00	0.20	0.00	0.00	1.60	59

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT DRUM NY	NERO	Wastewater	1.00	0.36	0.20	0.00	0.00	1.56	60
FORT POLK LA	SWRO	Heat/AC	0.00	0.50	1.00	0.00	0.00	1.50	62
ROCK ISLAND ARSENAL IL	NWRO	Natural Gas	0.00	0.50	1.00	0.00	0.00	1.50	62
FORT EUSTIS VA	NERO	Heat/AC	0.00	0.66	0.80	0.00	0.00	1.46	64
FORT GORDON GA	SERO	Heat/AC	0.00	0.60	0.80	0.00	0.00	1.40	65
ROCK ISLAND ARSENAL IL	NWRO	Wastewater	0.00	0.40	1.00	0.00	0.00	1.40	66
DETROIT ARSENAL MI	NWRO	Wastewater	0.80	0.56	0.00	0.00	0.00	1.36	67
DETROIT ARSENAL MI	NWRO	Water	0.80	0.56	0.00	0.00	0.00	1.36	67
DETROIT ARSENAL MI	NWRO	Electric	0.80	0.40	0.00	0.00	0.00	1.20	69
WEST POINT MIL RESERVATION NY	NERO	Natural Gas	0.40	0.56	0.20	0.00	0.00	1.16	70
FORT LEONARD WOOD MO	NWRO	Heat/AC	0.00	0.96	0.20	0.00	0.00	1.16	71
SOLDIER SYSTEMS CENTER MA	NERO	Heat/AC	0.00	0.96	0.20	0.00	0.00	1.16	71
WEST POINT MIL RESERVATION NY	NERO	Electric	0.40	0.46	0.20	0.00	0.00	1.06	73
FORT HUACHUCA AZ	SWRO	Water	0.00	0.60	0.20	0.20	0.00	1.00	75
FORT MYER VA	NERO	Wastewater	0.00	0.80	0.20	0.00	0.00	1.00	75
HUNTER ARMY AIRFIELD GA	SERO	Wastewater	0.00	0.60	0.00	0.00	0.40	1.00	75
ADELPHI LABORATORY CTR MD	NERO	Water	0.00	0.56	0.20	0.20	0.00	0.96	80
FORT HUACHUCA AZ	SWRO	Natural Gas	0.00	0.66	0.20	0.00	0.00	0.86	81
FORT KNOX KY	SERO	Heat/AC	0.00	0.66	0.20	0.00	0.00	0.86	81
FORT KNOX KY	SERO	Natural Gas	0.00	0.66	0.20	0.00	0.00	0.86	81
FORT MYER VA	NERO	Heat/AC	0.00	0.66	0.20	0.00	0.00	0.86	81
ADELPHI LABORATORY CTR MD	NERO	Heat/AC	0.00	0.66	0.20	0.00	0.00	0.86	81
HUNTER ARMY AIRFIELD GA	SERO	Heat/AC	0.00	0.86	0.00	0.00	0.00	0.86	86
CARLISLE BARRACKS PA	NERO	Electric	0.00	0.60	0.20	0.00	0.00	0.80	87
FORT MCCOY WI	NWRO	Wastewater	0.00	0.60	0.20	0.00	0.00	0.80	87
HUNTER ARMY AIRFIELD GA	SERO	Water	0.00	0.40	0.00	0.00	0.40	0.80	87
SOLDIER SYSTEMS CENTER MA	NERO	Wastewater	0.00	0.60	0.20	0.00	0.00	0.80	87
FORT LESLEY J MCNAIR VA	NERO	Wastewater	0.00	0.56	0.20	0.00	0.00	0.76	92
FORT MCCOY WI	NWRO	Heat/AC	0.00	0.56	0.20	0.00	0.00	0.76	92
ADELPHI LABORATORY CTR MD	NERO	Electric	0.00	0.56	0.20	0.00	0.00	0.76	92
ADELPHI LABORATORY CTR MD	NERO	Wastewater	0.00	0.50	0.20	0.00	0.00	0.70	96
CARLISLE BARRACKS PA	NERO	Natural Gas	0.00	0.46	0.20	0.00	0.00	0.66	97
FORT HUACHUCA AZ	SWRO	Heat/AC	0.00	0.46	0.20	0.00	0.00	0.66	97
FORT HUACHUCA AZ	SWRO	Wastewater	0.00	0.46	0.20	0.00	0.00	0.66	97
CARLISLE BARRACKS PA	NERO	Wastewater	0.00	0.40	0.20	0.00	0.00	0.60	100
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Wastewater	0.00	0.56	0.00	0.00	0.00	0.56	101
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Water	0.00	0.56	0.00	0.00	0.00	0.56	101
YAKIMA TRAINING CENTER WA	NWRO	Wastewater	0.00	0.56	0.00	0.00	0.00	0.56	101

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Natural Gas	0.00	0.50	0.00	0.00	0.00	0.50	106
YAKIMA TRAINING CENTER WA	NWRO	Water	0.00	0.30	0.00	0.00	0.20	0.50	106
CAMP ZAMA JAPAN	PARO	Heat/AC	0.00	0.46	0.00	0.00	0.00	0.46	108
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Electric	0.00	0.36	0.00	0.00	0.00	0.36	109
YAKIMA TRAINING CENTER WA	NWRO	Electric	0.00	0.36	0.00	0.00	0.00	0.36	109

Appendix B: Sensitivity Analyses — Effect of Changes on Overall Weighted Ratings and Rankings

The prioritization approach was tested by means of three types of sensitivity analyses to determine if the changes in the overall weighted ratings affected the outcomes of the rankings.

Sensitivity Analysis #1: Changes in ranges

Overall quality improvement to C-1/Q-1 (green rating)

Quality improvement cost to C-1/Q-1

Original Ranges:

1 = 0 to $500K; **2** = $501K to $1,000K; **3** = $1,001K to $1,500K; **4** = $1,501K to $2,000K; **5** = $2,001K or greater

New Ranges:

1 = 0 to $400K; **2** = $401K to $800K; **3** = $801K to $1,200K; **4** = $1,201K to $1,600K; **5** = $1,601K or greater

Age

Original Ranges:

1 = 0 to 10 years; **2** = 11 to 20 years; **3** = 21 to 30 years; **4** = 31 to 40 years; **5** = 41 years or greater

New Ranges:

1 = 0 to 5 years; **2** = 6 to 10 years; **3** = 11 to 15 years; **4** = 16 to 20 years; **5** = 21 years or greater

Capacity

Original Ranges:

1 = <=80% of average; **2** = 81% to 100% of average; **3** = 101% to 110% of average; **4** = 111% to 120% of average; **5** = >120% of average

New Ranges:

1 = <=70% of average; **2** = 71% to 90% of average; **3** = 91% to 110% of average; **4** = 111% to 130% of average; **5** = >131% of average

Cost

Original Ranges:

1 = <=80% of average; **2** = 81% to 100% of average; **3** = 101% to 110% of average; **4** = 111% to 120% of average; **5** = >120% of average

New Ranges:

1 = <=70% of average; **2** = 71% to 90% of average; **3** = 91% to 110% of average; **4** = 111% to 130% of average; **5** = >131% of average

Impact on mission dependency

Original Ranges:

1 = 199 and below; **2** = 200 to 399; **3** = 400 - 599; **4** = 600 to 799; **5** = 800 and greater

New Ranges:

1 = 249 and below; **2** = 250 to 499; **3** = 500 - 749; **4** = 750 to 999; **5** = 1000 and greater

Significant air or water quality violations reported

Original Ranges:

1 = 0 to 2 violations; **2** = 3 to 5 violations; **3** = 6 to 8 violations; **4** = 9 to 11 violations; **5** = 12 violations and greater

New Ranges:

1 = 0 to 4 violations; **2** = 5 to 9 violations; **3** = 10 to 14 violations; **4** = 15 to 19 violations; **5** = 20 violations and greater

Energy per square foot reduction

Original Ranges:

1 = 1.33% and greater; **2** = 0.33% to 1.329%; **3** = -0.67% to 0.329%; **4** = -1.67% to -0.671%; **5** = -1.671% and below

New Ranges:

1 = 2% and greater; **2** = 1.5% to 1.99%; **3** = 1% to 1.49%; **4** = 0.5% to 0.99%; 5 = 0.49% and below

Water consumption reduction

Original Ranges:

1 = 3% and greater; **2** = 2.5% to 2.99%; **3** = 2% to 2.49%; **4** = 1.5% to 1.99%; **5** = 1.49% and below

New Ranges:

1 = 2% and greater; **2** = 1.5% to 1.99%; **3** = 1% to 1.49%; **4** = 0.5% to 0.99%; **5** = 0.49% and below

Table B1 shows the rankings based on the results of Sensitivity Analysis #1.

Table B1. Results of rankings from Sensitivity Analysis #1.

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT GEORGE G MEADE MD	NERO	Heat/AC	1.00	0.80	1.00	0.00	0.20	3.00	1
FORT BRAGG NC	SERO	Heat/AC	1.00	0.66	1.00	0.00	0.20	2.86	2
FORT DRUM NY	NERO	Water	1.00	0.80	0.20	0.20	0.60	2.80	3
FORT SILL OK	SWRO	Heat/AC	1.00	0.80	1.00	0.00	0.00	2.80	4
FORT BELVOIR VA	NERO	Heat/AC	1.00	0.56	1.00	0.00	0.20	2.76	5
FORT LEE VA	NERO	Natural Gas	1.00	0.66	1.00	0.00	0.00	2.66	6
FORT SAM HOUSTON TX	SWRO	Heat/AC	1.00	0.60	1.00	0.00	0.00	2.60	7
FORT SILL OK	SWRO	Electric	1.00	0.60	1.00	0.00	0.00	2.60	7
REDSTONE ARSENAL AL	SERO	Heat/AC	0.60	0.86	1.00	0.00	0.00	2.46	9
FORT HOOD TX	SWRO	Heat/AC	1.00	0.40	1.00	0.00	0.00	2.40	10
FORT STEWART GA	SERO	Water	1.00	0.60	0.20	0.20	0.40	2.40	10
FORT JACKSON SC	SERO	Heat/AC	0.60	0.66	0.80	0.00	0.20	2.26	12
FORT RILEY KS	NWRO	Water	1.00	0.60	0.20	0.20	0.20	2.20	13
FORT DIX NJ	NERO	Heat/AC	0.40	0.76	1.00	0.00	0.00	2.16	14
FORT BENNING GA	SERO	Heat/AC	1.00	0.70	0.20	0.00	0.20	2.10	15
ROCK ISLAND ARSENAL IL	NWRO	Heat/AC	0.00	0.90	1.00	0.00	0.20	2.10	15
FORT LEWIS WA	NWRO	Heat/AC	1.00	0.66	0.20	0.00	0.20	2.06	17
ROCK ISLAND ARSENAL IL	NWRO	Water	0.00	0.66	1.00	0.20	0.20	2.06	17
ABERDEEN PROVING GROUND MD	NERO	Heat/AC	1.00	0.80	0.20	0.00	0.00	2.00	19
DUGWAY PROVING GROUND UT	NWRO	Electric	0.00	1.00	1.00	0.00	0.00	2.00	19
DUGWAY PROVING GROUND UT	NWRO	Water	0.00	0.80	1.00	0.20	0.00	2.00	19
FORT CARSON CO	NWRO	Wastewater	1.00	0.80	0.20	0.00	0.00	2.00	19
FORT CARSON CO	NWRO	Water	1.00	0.60	0.20	0.20	0.00	2.00	19
FORT DRUM NY	NERO	Electric	1.00	0.80	0.20	0.00	0.00	2.00	19
FORT MYER VA	NERO	Water	0.00	0.80	0.20	1.00	0.00	2.00	19
FORT WAINWRIGHT AK	PARO	Heat/AC	1.00	1.00	0.00	0.00	0.00	2.00	19
FORT CAMPBELL KY	SERO	Heat/AC	1.00	0.80	0.20	0.00	0.00	2.00	19
NTC AND FORT IRWIN CA	SWRO	Natural Gas	0.00	1.00	1.00	0.00	0.00	2.00	19
FORT CARSON CO	NWRO	Heat/AC	1.00	0.76	0.20	0.00	0.00	1.96	29
FORT STEWART GA	SERO	Wastewater	1.00	0.70	0.20	0.00	0.00	1.90	30
DUGWAY PROVING GROUND UT	NWRO	Heat/AC	0.00	0.90	1.00	0.00	0.00	1.90	31
FORT CARSON CO	NWRO	Electric	1.00	0.66	0.20	0.00	0.00	1.86	32
FORT DRUM NY	NERO	Natural Gas	1.00	0.66	0.20	0.00	0.00	1.86	32
FORT JACKSON SC	SERO	Natural Gas	0.60	0.46	0.80	0.00	0.00	1.86	32

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT LEAVENWORTH KS	NWRO	Natural Gas	0.20	0.66	1.00	0.00	0.00	1.86	32
FORT LESLEY J MCNAIR VA	NERO	Water	0.00	0.66	0.20	1.00	0.00	1.86	32
FORT RUCKER AL	SERO	Heat/AC	1.00	0.46	0.20	0.00	0.20	1.86	37
WHITE SANDS MISSLE RANGE NM	SWRO	Heat/AC	0.00	0.86	1.00	0.00	0.00	1.86	37
FORT LEAVENWORTH KS	NWRO	Heat/AC	0.20	0.60	1.00	0.00	0.00	1.80	39
FORT STEWART GA	SERO	Heat/AC	1.00	0.60	0.20	0.00	0.00	1.80	39
ABERDEEN PROVING GROUND MD	NERO	Wastewater	1.00	0.56	0.20	0.00	0.00	1.76	41
FORT CARSON CO	NWRO	Natural Gas	1.00	0.56	0.20	0.00	0.00	1.76	41
FORT HUNTER LIGGETT CA	SWRO	Natural Gas	0.20	0.56	1.00	0.00	0.00	1.76	41
FORT MCCOY WI	NWRO	Water	0.00	0.36	0.20	1.00	0.20	1.76	41
FORT RILEY KS	NWRO	Heat/AC	1.00	0.56	0.20	0.00	0.00	1.76	41
FORT RILEY KS	NWRO	Natural Gas	1.00	0.56	0.20	0.00	0.00	1.76	41
FORT RILEY KS	NWRO	Wastewater	1.00	0.56	0.20	0.00	0.00	1.76	41
PICATINNY ARSENAL NJ	NERO	Heat/AC	0.60	0.96	0.20	0.00	0.00	1.76	41
FORT EUSTIS VA	NERO	Heat/AC	0.00	0.70	1.00	0.00	0.00	1.70	49
FORT BLISS TX	SWRO	Heat/AC	1.00	0.50	0.20	0.00	0.00	1.70	50
FORT CAMPBELL KY	SERO	Electric	1.00	0.50	0.20	0.00	0.00	1.70	50
FORT GORDON GA	SERO	Heat/AC	0.00	0.66	1.00	0.00	0.00	1.66	52
NTC AND FORT IRWIN CA	SWRO	Heat/AC	0.00	0.66	1.00	0.00	0.00	1.66	52
WEST POINT MIL RESERVATION NY	NERO	Heat/AC	0.40	0.86	0.20	0.00	0.20	1.66	54
DUGWAY PROVING GROUND UT	NWRO	Wastewater	0.00	0.60	1.00	0.00	0.00	1.60	55
FORT POLK LA	SWRO	Heat/AC	0.00	0.60	1.00	0.00	0.00	1.60	55
ROCK ISLAND ARSENAL IL	NWRO	Electric	0.00	0.60	1.00	0.00	0.00	1.60	55
SCHOFIELD BKS MIL RESERVE HI	PARO	Heat/AC	1.00	0.60	0.00	0.00	0.00	1.60	55
SOLDIER SYSTEMS CENTER MA	NERO	Water	0.00	0.40	0.20	1.00	0.00	1.60	55
FORT RICHARDSON AK	PARO	Heat/AC	0.40	1.00	0.20	0.00	0.00	1.60	60
FORT DRUM NY	NERO	Wastewater	1.00	0.36	0.20	0.00	0.00	1.56	61
YUMA PROVING GROUND AZ	SWRO	Heat/AC	0.00	0.56	1.00	0.00	0.00	1.56	61
ROCK ISLAND ARSENAL IL	NWRO	Natural Gas	0.00	0.50	1.00	0.00	0.00	1.50	63
CARLISLE BARRACKS PA	NERO	Water	0.00	0.60	0.20	0.60	0.00	1.40	64
ROCK ISLAND ARSENAL IL	NWRO	Wastewater	0.00	0.40	1.00	0.00	0.00	1.40	65
WEST POINT MIL RESERVATION NY	NERO	Natural Gas	0.40	0.60	0.20	0.00	0.00	1.20	67
DETROIT ARSENAL MI	NWRO	Wastewater	0.60	0.56	0.00	0.00	0.00	1.16	68
DETROIT ARSENAL MI	NWRO	Water	0.60	0.56	0.00	0.00	0.00	1.16	68
FORT LEONARD WOOD MO	NWRO	Heat/AC	0.00	0.96	0.20	0.00	0.00	1.16	70
SOLDIER SYSTEMS CENTER MA	NERO	Heat/AC	0.00	0.96	0.20	0.00	0.00	1.16	70
WEST POINT MIL RESERVATION NY	NERO	Electric	0.40	0.50	0.20	0.00	0.00	1.10	72
DETROIT ARSENAL MI	NWRO	Electric	0.60	0.40	0.00	0.00	0.00	1.00	74

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT HUACHUCA AZ	SWRO	Water	0.00	0.60	0.20	0.20	0.00	1.00	74
FORT MYER VA	NERO	Wastewater	0.00	0.80	0.20	0.00	0.00	1.00	74
HUNTER ARMY AIRFIELD GA	SERO	Wastewater	0.00	0.60	0.00	0.00	0.40	1.00	74
ADELPHI LABORATORY CTR MD	NERO	Water	0.00	0.60	0.20	0.20	0.00	1.00	74
FORT HUACHUCA AZ	SWRO	Natural Gas	0.00	0.70	0.20	0.00	0.00	0.90	80
FORT KNOX KY	SERO	Heat/AC	0.00	0.70	0.20	0.00	0.00	0.90	80
FORT MYER VA	NERO	Heat/AC	0.00	0.70	0.20	0.00	0.00	0.90	80
USA ADELPHI LABORATORY CTR	NERO	Heat/AC	0.00	0.70	0.20	0.00	0.00	0.90	80
FORT KNOX KY	SERO	Natural Gas	0.00	0.66	0.20	0.00	0.00	0.86	84
HUNTER ARMY AIRFIELD GA	SERO	Heat/AC	0.00	0.86	0.00	0.00	0.00	0.86	86
CARLISLE BARRACKS PA	NERO	Electric	0.00	0.60	0.20	0.00	0.00	0.80	87
FORT MCCOY WI	NWRO	Wastewater	0.00	0.60	0.20	0.00	0.00	0.80	87
SOLDIER SYSTEMS CENTER MA	NERO	Wastewater	0.00	0.60	0.20	0.00	0.00	0.80	87
ADELPHI LABORATORY CTR MD	NERO	Electric	0.00	0.60	0.20	0.00	0.00	0.80	87
FORT HUACHUCA AZ	SWRO	Heat/AC	0.00	0.56	0.20	0.00	0.00	0.76	91
FORT HUACHUCA AZ	SWRO	Wastewater	0.00	0.56	0.20	0.00	0.00	0.76	91
FORT LESLEY J MCNAIR VA	NERO	Wastewater	0.00	0.56	0.20	0.00	0.00	0.76	91
FORT MCCOY WI	NWRO	Heat/AC	0.00	0.56	0.20	0.00	0.00	0.76	91
ADELPHI LABORATORY CTR MD	NERO	Wastewater	0.00	0.56	0.20	0.00	0.00	0.76	91
CARLISLE BARRACKS PA	NERO	Natural Gas	0.00	0.50	0.20	0.00	0.00	0.70	98
CARLISLE BARRACKS PA	NERO	Wastewater	0.00	0.40	0.20	0.00	0.00	0.60	99
HUNTER ARMY AIRFIELD GA	SERO	Water	0.00	0.40	0.00	0.00	0.20	0.60	99
YAKIMA TRAINING CENTER WA	NWRO	Water	0.00	0.40	0.00	0.00	0.20	0.60	99
CAMP ZAMA JAPAN	PARO	Heat/AC	0.00	0.56	0.00	0.00	0.00	0.56	102
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Wastewater	0.00	0.56	0.00	0.00	0.00	0.56	102
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Water	0.00	0.56	0.00	0.00	0.00	0.56	102
YAKIMA TRAINING CENTER WA	NWRO	Wastewater	0.00	0.56	0.00	0.00	0.00	0.56	102
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Natural Gas	0.00	0.50	0.00	0.00	0.00	0.50	107
HAWTHORNE ARMY DEPOT NV	SWRO	Wastewater	0.00	0.50	0.00	0.00	0.00	0.50	107
YAKIMA TRAINING CENTER WA	NWRO	Electric	0.00	0.46	0.00	0.00	0.00	0.46	109
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Electric	0.00	0.36	0.00	0.00	0.00	0.36	110

Sensitivity Analysis #2: Changes in weighting factors without changes in ranges

Original weighting factors

Overall Quality Improvement to C-1/Q-1 (Green Rating)	**0.2**
Impact on Mission Dependency	**0.2**
Significant Air or Water Quality Violations Reported	**0.2**
Energy per Square Foot Reduction	**0.2**
Water Consumption Reduction	**0.2**

New weighting factors

Overall Quality Improvement to C-1/Q-1 (Green Rating)	0.4
Impact on Mission Dependency	0.3
Significant Air or Water Quality Violations Reported	0.1
Energy per Square Foot Reduction	0.1
Water Consumption Reduction	0.1

Table B2 shows the rankings based on the results of Sensitivity Analysis #2.

Table B2. Results of rankings from Sensitivity Analysis #2.

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT DRUM NY	NERO	Water	2.00	1.20	0.10	0.10	0.40	3.80	1
FORT GEORGE G MEADE MD	NERO	Heat/AC	2.00	1.20	0.50	0.00	0.10	3.80	1
FORT BRAGG NC	SERO	Heat/AC	2.00	0.99	0.50	0.00	0.10	3.59	3
FORT LEE VA	NERO	Natural Gas	2.00	1.05	0.50	0.00	0.00	3.55	4
FORT WAINWRIGHT AK	PARO	Heat/AC	2.00	1.50	0.00	0.00	0.00	3.50	5
FORT SILL OK	SWRO	Heat/AC	2.00	1.14	0.30	0.00	0.00	3.44	6
FORT BELVOIR VA	NERO	Heat/AC	2.00	0.84	0.50	0.00	0.10	3.44	7

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT STEWART GA	SERO	Water	2.00	0.90	0.10	0.10	0.30	3.40	8
REDSTONE ARSENAL AL	SERO	Heat/AC	1.60	1.29	0.50	0.00	0.00	3.39	9
FORT CARSON CO	NWRO	Wastewater	2.00	1.20	0.10	0.00	0.00	3.30	10
FORT DRUM NY	NERO	Electric	2.00	1.20	0.10	0.00	0.00	3.30	10
FORT RILEY KS	NWRO	Water	2.00	0.90	0.10	0.10	0.20	3.30	10
FORT CAMPBELL KY	SERO	Heat/AC	2.00	1.20	0.10	0.00	0.00	3.30	10
FORT CARSON CO	NWRO	Heat/AC	2.00	1.14	0.10	0.00	0.00	3.24	14
FORT SILL OK	SWRO	Electric	2.00	0.90	0.30	0.00	0.00	3.20	15
PICATINNY ARSENAL NJ	NERO	Heat/AC	1.60	1.50	0.10	0.00	0.00	3.20	15
FORT BENNING GA	SERO	Heat/AC	2.00	0.99	0.10	0.00	0.10	3.19	17
ABERDEEN PROVING GROUND MD	NERO	Heat/AC	2.00	1.05	0.10	0.00	0.00	3.15	18
FORT LEWIS WA	NWRO	Heat/AC	2.00	0.84	0.10	0.00	0.20	3.14	19
FORT SAM HOUSTON TX	SWRO	Heat/AC	2.00	0.84	0.30	0.00	0.00	3.14	20
FORT CARSON CO	NWRO	Water	2.00	0.90	0.10	0.10	0.00	3.10	21
FORT HOOD TX	SWRO	Heat/AC	2.00	0.60	0.50	0.00	0.00	3.10	21
FORT STEWART GA	SERO	Wastewater	2.00	0.99	0.10	0.00	0.00	3.09	23
FORT CARSON CO	NWRO	Electric	2.00	0.90	0.10	0.00	0.00	3.00	24
ABERDEEN PROVING GROUND MD	NERO	Wastewater	2.00	0.84	0.10	0.00	0.00	2.94	25
FORT CARSON CO	NWRO	Natural Gas	2.00	0.84	0.10	0.00	0.00	2.94	25
FORT DRUM NY	NERO	Natural Gas	2.00	0.84	0.10	0.00	0.00	2.94	25
FORT RILEY KS	NWRO	Heat/AC	2.00	0.84	0.10	0.00	0.00	2.94	25
SCHOFIELD BKS MIL RESERVE HI	PARO	Heat/AC	2.00	0.90	0.00	0.00	0.00	2.90	29
FORT RUCKER AL	SERO	Heat/AC	2.00	0.69	0.10	0.00	0.10	2.89	30
FORT STEWART GA	SERO	Heat/AC	2.00	0.75	0.10	0.00	0.00	2.85	31
FORT CAMPBELL KY	SERO	Electric	2.00	0.75	0.10	0.00	0.00	2.85	31
FORT JACKSON SC	SERO	Heat/AC	1.60	0.90	0.20	0.00	0.10	2.80	33
FORT BLISS TX	SWRO	Heat/AC	2.00	0.69	0.10	0.00	0.00	2.79	34
FORT RILEY KS	NWRO	Natural Gas	2.00	0.69	0.10	0.00	0.00	2.79	34
FORT RILEY KS	NWRO	Wastewater	2.00	0.69	0.10	0.00	0.00	2.79	34
FORT DRUM NY	NERO	Wastewater	2.00	0.54	0.10	0.00	0.00	2.64	37
DETROIT ARSENAL MI	NWRO	Wastewater	1.60	0.84	0.00	0.00	0.00	2.44	38
DETROIT ARSENAL MI	NWRO	Water	1.60	0.84	0.00	0.00	0.00	2.44	38
FORT DIX NJ	NERO	Heat/AC	0.80	1.14	0.50	0.00	0.00	2.44	38
FORT JACKSON SC	SERO	Natural Gas	1.60	0.60	0.20	0.00	0.00	2.40	41
FORT RICHARDSON AK	PARO	Heat/AC	0.80	1.50	0.10	0.00	0.00	2.40	42
FORT LEAVENWORTH KS	NWRO	Natural Gas	0.80	1.05	0.50	0.00	0.00	2.35	43
DETROIT ARSENAL MI	NWRO	Electric	1.60	0.60	0.00	0.00	0.00	2.20	44
WEST POINT MIL RESERVATION NY	NERO	Heat/AC	0.80	1.20	0.10	0.00	0.10	2.20	44

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT LEAVENWORTH KS	NWRO	Heat/AC	0.80	0.84	0.50	0.00	0.00	2.14	46
DUGWAY PROVING GROUND UT	NWRO	Electric	0.00	1.50	0.50	0.00	0.00	2.00	47
NTC AND FORT IRWIN CA	SWRO	Natural Gas	0.00	1.50	0.50	0.00	0.00	2.00	47
ROCK ISLAND ARSENAL IL	NWRO	Heat/AC	0.00	1.35	0.50	0.00	0.10	1.95	49
WHITE SANDS MISSLE RANGE NM	SWRO	Heat/AC	0.00	1.35	0.50	0.00	0.00	1.85	50
DUGWAY PROVING GROUND UT	NWRO	Water	0.00	1.20	0.50	0.10	0.00	1.80	51
FORT MYER VA	NERO	Water	0.00	1.20	0.10	0.50	0.00	1.80	51
ROCK ISLAND ARSENAL IL	NWRO	Water	0.00	0.99	0.50	0.20	0.10	1.79	53
DUGWAY PROVING GROUND UT	NWRO	Heat/AC	0.00	1.29	0.50	0.00	0.00	1.79	54
FORT HUNTER LIGGETT CA	SWRO	Natural Gas	0.40	0.84	0.50	0.00	0.00	1.74	55
WEST POINT MIL RESERVATION NY	NERO	Natural Gas	0.80	0.84	0.10	0.00	0.00	1.74	55
WEST POINT MIL RESERVATION NY	NERO	Electric	0.80	0.69	0.10	0.00	0.00	1.59	57
FORT LEONARD WOOD MO	NWRO	Heat/AC	0.00	1.44	0.10	0.00	0.00	1.54	58
SOLDIER SYSTEMS CENTER MA	NERO	Heat/AC	0.00	1.44	0.10	0.00	0.00	1.54	58
CARLISLE BARRACKS PA	NERO	Water	0.00	0.90	0.10	0.50	0.00	1.50	60
FORT LESLEY J MCNAIR VA	NERO	Water	0.00	0.90	0.10	0.50	0.00	1.50	60
NTC AND FORT IRWIN CA	SWRO	Heat/AC	0.00	0.99	0.50	0.00	0.00	1.49	62
DUGWAY PROVING GROUND UT	NWRO	Wastewater	0.00	0.90	0.50	0.00	0.00	1.40	64
ROCK ISLAND ARSENAL IL	NWRO	Electric	0.00	0.90	0.50	0.00	0.00	1.40	64
YUMA PROVING GROUND AZ	SWRO	Heat/AC	0.00	0.90	0.50	0.00	0.00	1.40	64
FORT EUSTIS VA	NERO	Heat/AC	0.00	0.99	0.40	0.00	0.00	1.39	67
FORT MYER VA	NERO	Wastewater	0.00	1.20	0.10	0.00	0.00	1.30	68
FORT GORDON GA	SERO	Heat/AC	0.00	0.90	0.40	0.00	0.00	1.30	69
HUNTER ARMY AIRFIELD GA	SERO	Heat/AC	0.00	1.29	0.00	0.00	0.00	1.29	70
FORT POLK LA	SWRO	Heat/AC	0.00	0.75	0.50	0.00	0.00	1.25	71
ROCK ISLAND ARSENAL IL	NWRO	Natural Gas	0.00	0.75	0.50	0.00	0.00	1.25	71
FORT MCCOY WI	NWRO	Water	0.00	0.54	0.10	0.50	0.10	1.24	73
SOLDIER SYSTEMS CENTER MA	NERO	Water	0.00	0.60	0.10	0.50	0.00	1.20	74
ROCK ISLAND ARSENAL IL	NWRO	Wastewater	0.00	0.60	0.50	0.00	0.00	1.10	76
FORT HUACHUCA AZ	SWRO	Water	0.00	0.90	0.10	0.10	0.00	1.10	77
HUNTER ARMY AIRFIELD GA	SERO	Wastewater	0.00	0.90	0.00	0.00	0.20	1.10	77
FORT HUACHUCA AZ	SWRO	Natural Gas	0.00	0.99	0.10	0.00	0.00	1.09	80
FORT KNOX KY	SERO	Heat/AC	0.00	0.99	0.10	0.00	0.00	1.09	80
FORT KNOX KY	SERO	Natural Gas	0.00	0.99	0.10	0.00	0.00	1.09	80
FORT MYER VA	NERO	Heat/AC	0.00	0.99	0.10	0.00	0.00	1.09	80
ADELPHI LABORATORY CTR MD	NERO	Heat/AC	0.00	0.99	0.10	0.00	0.00	1.09	80
ADELPHI LABORATORY CTR MD	NERO	Water	0.00	0.84	0.10	0.10	0.00	1.04	85
CARLISLE BARRACKS PA	NERO	Electric	0.00	0.90	0.10	0.00	0.00	1.00	87

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT MCCOY WI	NWRO	Wastewater	0.00	0.90	0.10	0.00	0.00	1.00	87
SOLDIER SYSTEMS CENTER MA	NERO	Wastewater	0.00	0.90	0.10	0.00	0.00	1.00	87
FORT LESLEY J MCNAIR VA	NERO	Wastewater	0.00	0.84	0.10	0.00	0.00	0.94	91
FORT MCCOY WI	NWRO	Heat/AC	0.00	0.84	0.10	0.00	0.00	0.94	91
ADELPHI LABORATORY CTR MD	NERO	Electric	0.00	0.84	0.10	0.00	0.00	0.94	91
ADELPHI LABORATORY CTR MD	NERO	Wastewater	0.00	0.75	0.10	0.00	0.00	0.85	95
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Wastewater	0.00	0.84	0.00	0.00	0.00	0.84	96
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Water	0.00	0.84	0.00	0.00	0.00	0.84	96
YAKIMA TRAINING CENTER WA	NWRO	Wastewater	0.00	0.84	0.00	0.00	0.00	0.84	96
HUNTER ARMY AIRFIELD GA	SERO	Water	0.00	0.60	0.00	0.00	0.20	0.80	101
CARLISLE BARRACKS PA	NERO	Natural Gas	0.00	0.69	0.10	0.00	0.00	0.79	102
FORT HUACHUCA AZ	SWRO	Heat/AC	0.00	0.69	0.10	0.00	0.00	0.79	102
FORT HUACHUCA AZ	SWRO	Wastewater	0.00	0.69	0.10	0.00	0.00	0.79	102
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Natural Gas	0.00	0.75	0.00	0.00	0.00	0.75	105
CARLISLE BARRACKS PA	NERO	Wastewater	0.00	0.60	0.10	0.00	0.00	0.70	106
CAMP ZAMA JAPAN	PARO	Heat/AC	0.00	0.69	0.00	0.00	0.00	0.69	107
YAKIMA TRAINING CENTER WA	NWRO	Water	0.00	0.45	0.00	0.00	0.10	0.55	108
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Electric	0.00	0.54	0.00	0.00	0.00	0.54	109
YAKIMA TRAINING CENTER WA	NWRO	Electric	0.00	0.54	0.00	0.00	0.00	0.54	109

Sensitivity Analysis #3: Changes in both ranges and weighting factors

This sensitivity analysis combines Sensitivity Analysis #1 with Sensitivity Analysis #2. Table B3 shows the rankings based on the results of Sensitivity Analysis #3.

Table B3. Results of rankings from Sensitivity Analysis #3.

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT GEORGE G MEADE MD	NERO	Heat/AC	2.00	1.20	0.50	0.00	0.10	3.80	1
FORT DRUM NY	NERO	Water	2.00	1.20	0.10	0.10	0.30	3.70	2
FORT SILL OK	SWRO	Heat/AC	2.00	1.20	0.50	0.00	0.00	3.70	2
FORT BRAGG NC	SERO	Heat/AC	2.00	0.99	0.50	0.00	0.10	3.59	4
FORT WAINWRIGHT AK	PARO	Heat/AC	2.00	1.50	0.00	0.00	0.00	3.50	5
FORT LEE VA	NERO	Natural Gas	2.00	0.99	0.50	0.00	0.00	3.49	6
FORT BELVOIR VA	NERO	Heat/AC	2.00	0.84	0.50	0.00	0.10	3.44	7
FORT SAM HOUSTON TX	SWRO	Heat/AC	2.00	0.90	0.50	0.00	0.00	3.40	8
FORT SILL OK	SWRO	Electric	2.00	0.90	0.50	0.00	0.00	3.40	8
ABERDEEN PROVING GROUND MD	NERO	Heat/AC	2.00	1.20	0.10	0.00	0.00	3.30	10
FORT CARSON CO	NWRO	Wastewater	2.00	1.20	0.10	0.00	0.00	3.30	10
FORT DRUM NY	NERO	Electric	2.00	1.20	0.10	0.00	0.00	3.30	10
FORT STEWART GA	SERO	Water	2.00	0.90	0.10	0.10	0.20	3.30	10
FORT CAMPBELL KY	SERO	Heat/AC	2.00	1.20	0.10	0.00	0.00	3.30	10
FORT BENNING GA	SERO	Heat/AC	2.00	1.05	0.10	0.00	0.10	3.25	15
FORT CARSON CO	NWRO	Heat/AC	2.00	1.14	0.10	0.00	0.00	3.24	16
FORT RILEY KS	NWRO	Water	2.00	0.90	0.10	0.10	0.10	3.20	17
FORT LEWIS WA	NWRO	Heat/AC	2.00	0.99	0.10	0.00	0.10	3.19	18
FORT STEWART GA	SERO	Wastewater	2.00	1.05	0.10	0.00	0.00	3.15	19
FORT CARSON CO	NWRO	Water	2.00	0.90	0.10	0.10	0.00	3.10	20
FORT HOOD TX	SWRO	Heat/AC	2.00	0.60	0.50	0.00	0.00	3.10	20
FORT CARSON CO	NWRO	Electric	2.00	0.99	0.10	0.00	0.00	3.09	22
FORT DRUM NY	NERO	Natural Gas	2.00	0.99	0.10	0.00	0.00	3.09	22
FORT STEWART GA	SERO	Heat/AC	2.00	0.90	0.10	0.00	0.00	3.00	24
REDSTONE ARSENAL AL	SERO	Heat/AC	1.20	1.29	0.50	0.00	0.00	2.99	25
ABERDEEN PROVING GROUND MD	NERO	Wastewater	2.00	0.84	0.10	0.00	0.00	2.94	26
FORT CARSON CO	NWRO	Natural Gas	2.00	0.84	0.10	0.00	0.00	2.94	26
FORT RILEY KS	NWRO	Heat/AC	2.00	0.84	0.10	0.00	0.00	2.94	26
FORT RILEY KS	NWRO	Natural Gas	2.00	0.84	0.10	0.00	0.00	2.94	26
FORT RILEY KS	NWRO	Wastewater	2.00	0.84	0.10	0.00	0.00	2.94	26
SCHOFIELD BKS MIL RESERVE HI	PARO	Heat/AC	2.00	0.90	0.00	0.00	0.00	2.90	31

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
FORT RUCKER AL	SERO	Heat/AC	2.00	0.69	0.10	0.00	0.10	2.89	32
FORT BLISS TX	SWRO	Heat/AC	2.00	0.75	0.10	0.00	0.00	2.85	33
FORT CAMPBELL KY	SERO	Electric	2.00	0.75	0.10	0.00	0.00	2.85	33
PICATINNY ARSENAL NJ	NERO	Heat/AC	1.20	1.44	0.10	0.00	0.00	2.74	35
FORT JACKSON SC	SERO	Heat/AC	1.20	0.99	0.40	0.00	0.10	2.69	36
FORT DRUM NY	NERO	Wastewater	2.00	0.54	0.10	0.00	0.00	2.64	37
FORT DIX NJ	NERO	Heat/AC	0.80	1.14	0.50	0.00	0.00	2.44	38
FORT RICHARDSON AK	PARO	Heat/AC	0.80	1.50	0.10	0.00	0.00	2.40	39
FORT JACKSON SC	SERO	Natural Gas	1.20	0.69	0.40	0.00	0.00	2.29	40
WEST POINT MIL RESERVATION NY	NERO	Heat/AC	0.80	1.29	0.10	0.00	0.10	2.29	40
DETROIT ARSENAL MI	NWRO	Wastewater	1.20	0.84	0.00	0.00	0.00	2.04	42
DETROIT ARSENAL MI	NWRO	Water	1.20	0.84	0.00	0.00	0.00	2.04	42
DUGWAY PROVING GROUND UT	NWRO	Electric	0.00	1.50	0.50	0.00	0.00	2.00	44
NTC AND FORT IRWIN CA	SWRO	Natural Gas	0.00	1.50	0.50	0.00	0.00	2.00	44
ROCK ISLAND ARSENAL IL	NWRO	Heat/AC	0.00	1.35	0.50	0.00	0.10	1.95	46
FORT LEAVENWORTH KS	NWRO	Natural Gas	0.40	0.99	0.50	0.00	0.00	1.89	47
DUGWAY PROVING GROUND UT	NWRO	Heat/AC	0.00	1.35	0.50	0.00	0.00	1.85	48
DETROIT ARSENAL MI	NWRO	Electric	1.20	0.60	0.00	0.00	0.00	1.80	49
DUGWAY PROVING GROUND UT	NWRO	Water	0.00	1.20	0.50	0.10	0.00	1.80	50
FORT MYER VA	NERO	Water	0.00	1.20	0.10	0.50	0.00	1.80	50
WEST POINT MIL RESERVATION NY	NERO	Natural Gas	0.80	0.90	0.10	0.00	0.00	1.80	50
FORT LEAVENWORTH KS	NWRO	Heat/AC	0.40	0.90	0.50	0.00	0.00	1.80	53
WHITE SANDS MISSLE RANGE NM	SWRO	Heat/AC	0.00	1.29	0.50	0.00	0.00	1.79	54
FORT HUNTER LIGGETT CA	SWRO	Natural Gas	0.40	0.84	0.50	0.00	0.00	1.74	55
ROCK ISLAND ARSENAL IL	NWRO	Water	0.00	0.99	0.50	0.10	0.10	1.69	56
WEST POINT MIL RESERVATION NY	NERO	Electric	0.80	0.75	0.10	0.00	0.00	1.65	57
FORT LESLEY J MCNAIR VA	NERO	Water	0.00	0.99	0.10	0.50	0.00	1.59	58
FORT EUSTIS VA	NERO	Heat/AC	0.00	1.05	0.50	0.00	0.00	1.55	59
FORT LEONARD WOOD MO	NWRO	Heat/AC	0.00	1.44	0.10	0.00	0.00	1.54	60
SOLDIER SYSTEMS CENTER MA	NERO	Heat/AC	0.00	1.44	0.10	0.00	0.00	1.54	60
FORT GORDON GA	SERO	Heat/AC	0.00	0.99	0.50	0.00	0.00	1.49	62
NTC AND FORT IRWIN CA	SWRO	Heat/AC	0.00	0.99	0.50	0.00	0.00	1.49	62
DUGWAY PROVING GROUND UT	NWRO	Wastewater	0.00	0.90	0.50	0.00	0.00	1.40	64
FORT POLK LA	SWRO	Heat/AC	0.00	0.90	0.50	0.00	0.00	1.40	64
ROCK ISLAND ARSENAL IL	NWRO	Electric	0.00	0.90	0.50	0.00	0.00	1.40	64
YUMA PROVING GROUND AZ	SWRO	Heat/AC	0.00	0.84	0.50	0.00	0.00	1.34	68
FORT MYER VA	NERO	Wastewater	0.00	1.20	0.10	0.00	0.00	1.30	69
CARLISLE BARRACKS PA	NERO	Water	0.00	0.90	0.10	0.30	0.00	1.30	70

Installation Name	Region	Utility Category	Weighted Mission Dependency	Weighted Quality Improvement	Weighted Energy Reduction	Weighted Water Consumption Reduction	Weighted Violation Reporting	Total Weighted Rating	Rank
HUNTER ARMY AIRFIELD GA	SERO	Heat/AC	0.00	1.29	0.00	0.00	0.00	1.29	71
ROCK ISLAND ARSENAL IL	NWRO	Natural Gas	0.00	0.75	0.50	0.00	0.00	1.25	72
FORT MCCOY WI	NWRO	Water	0.00	0.54	0.10	0.50	0.10	1.24	73
SOLDIER SYSTEMS CENTER MA	NERO	Water	0.00	0.60	0.10	0.50	0.00	1.20	74
FORT HUACHUCA AZ	SWRO	Natural Gas	0.00	1.05	0.10	0.00	0.00	1.15	76
FORT KNOX KY	SERO	Heat/AC	0.00	1.05	0.10	0.00	0.00	1.15	76
FORT MYER VA	NERO	Heat/AC	0.00	1.05	0.10	0.00	0.00	1.15	76
ADELPHI LABORATORY CTR MD	NERO	Heat/AC	0.00	1.05	0.10	0.00	0.00	1.15	76
ROCK ISLAND ARSENAL IL	NWRO	Wastewater	0.00	0.60	0.50	0.00	0.00	1.10	80
FORT HUACHUCA AZ	SWRO	Water	0.00	0.90	0.10	0.10	0.00	1.10	81
HUNTER ARMY AIRFIELD GA	SERO	Wastewater	0.00	0.90	0.00	0.00	0.20	1.10	81
ADELPHI LABORATORY CTR MD	NERO	Water	0.00	0.90	0.10	0.10	0.00	1.10	81
FORT KNOX KY	SERO	Natural Gas	0.00	0.99	0.10	0.00	0.00	1.09	85
CARLISLE BARRACKS PA	NERO	Electric	0.00	0.90	0.10	0.00	0.00	1.00	87
FORT MCCOY WI	NWRO	Wastewater	0.00	0.90	0.10	0.00	0.00	1.00	87
SOLDIER SYSTEMS CENTER MA	NERO	Wastewater	0.00	0.90	0.10	0.00	0.00	1.00	87
ADELPHI LABORATORY CTR MD	NERO	Electric	0.00	0.90	0.10	0.00	0.00	1.00	87
FORT HUACHUCA AZ	SWRO	Heat/AC	0.00	0.84	0.10	0.00	0.00	0.94	91
FORT HUACHUCA AZ	SWRO	Wastewater	0.00	0.84	0.10	0.00	0.00	0.94	91
FORT LESLEY J MCNAIR VA	NERO	Wastewater	0.00	0.84	0.10	0.00	0.00	0.94	91
FORT MCCOY WI	NWRO	Heat/AC	0.00	0.84	0.10	0.00	0.00	0.94	91
ADELPHI LABORATORY CTR MD	NERO	Wastewater	0.00	0.84	0.10	0.00	0.00	0.94	91
CARLISLE BARRACKS PA	NERO	Natural Gas	0.00	0.75	0.10	0.00	0.00	0.85	98
CAMP ZAMA JAPAN	PARO	Heat/AC	0.00	0.84	0.00	0.00	0.00	0.84	99
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Wastewater	0.00	0.84	0.00	0.00	0.00	0.84	99
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Water	0.00	0.84	0.00	0.00	0.00	0.84	99
YAKIMA TRAINING CENTER WA	NWRO	Wastewater	0.00	0.84	0.00	0.00	0.00	0.84	99
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Natural Gas	0.00	0.75	0.00	0.00	0.00	0.75	104
CARLISLE BARRACKS PA	NERO	Wastewater	0.00	0.60	0.10	0.00	0.00	0.70	106
HUNTER ARMY AIRFIELD GA	SERO	Water	0.00	0.60	0.00	0.00	0.10	0.70	106
YAKIMA TRAINING CENTER WA	NWRO	Water	0.00	0.60	0.00	0.00	0.10	0.70	106
YAKIMA TRAINING CENTER WA	NWRO	Electric	0.00	0.69	0.00	0.00	0.00	0.69	109
FORT DOUGLAS AFRC COMPLEX UT	NWRO	Electric	0.00	0.54	0.00	0.00	0.00	0.54	110

Figure B1 illustrates the results of all three sensitivity analyses.

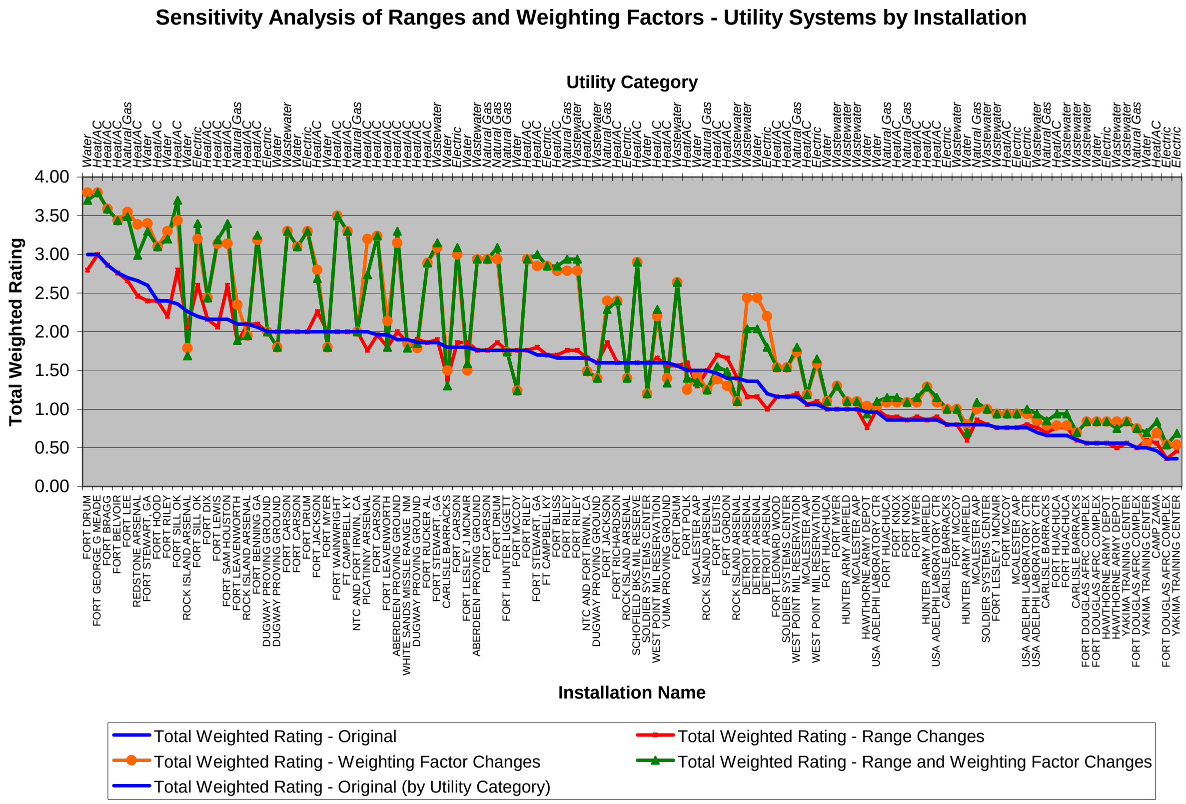


Figure B1. Comparisons of original rankings and results of sensitivity analyses.

Conclusions from sensitivity analyses

In performing the range changes only during Sensitivity Analysis #1, a majority of the weighted ratings were close to the original ratings. In performing the weighting factor changes only during Sensitivity Analysis #2, a majority of the weighted ratings led to significant increases from their original ratings and resulted in the change in the rankings of the utility systems. Similarly, a majority of the weighted ratings significantly increased due to changes in both ranges and weighting factors during Sensitivity Analyses #3, resulting again in changes in the rankings. The significant increase in the weighting factors, as a whole, occurred due to emphasis placed on weighting mission dependency and quality improvement costs. Fort Wainwright, for example, has significant future mission requirements as well as significantly high quality improvement costs, but AEWRS does not provide data on Fort Wainwright; hence, the true energy per square foot reduction cannot be determined, and therefore, no weighted rating could be determined for energy reduction. If AEWRS data were available for a variety of subinstallations (e.g., Fort Wainwright is a subinstallation of Fort Richardson), then the ratings in their utility systems would make a substantial difference in the project prioritization scheme because of more available detailed information. The sensitivity analyses will only improve if more data are available for each installation and its utility system.

Appendix C: Identification of Project Alternatives

Introduction

This appendix focuses on project alternatives for modernizing utility systems. The Utilities Modernization Program for FY08–13 will focus on systems *external* to the building and not on individual systems within buildings. The Utilities Modernization Program planning process should be *problem-driven* instead of solutions-driven and must focus first on the installation's requirements, then on the technologies that support those requirements. Once the problems are identified by each installation, then the solutions are better defined.

The following project alternatives will be discussed in further detail:

- Upgrades and refurbishments of existing central heating and distribution systems
- Full or partial decentralization of heating and/or cooling systems
- Low-temperature hot water heating distribution systems
- New central chilled water systems (satellite plants) or additions to existing systems
- Cogeneration
- Trigeneration
- Thermal storage cooling system for demand-side management.

Each project alternative will provide the following: (a) a general description of the alternative, (b) benefits of using the alternative, (c) disadvantages of using the alternative, (d) generic costs for using the alternative, and (e) if applicable, financing requirements and energy incentives for achieving cost-effective implementation of the alternative.

Upgrades and refurbishments of existing central heating and distribution systems

General description

A central heating system consists of one or more centralized plants that produce steam or hot water feeding a distribution piping system. The fuels used include fuel oil, natural gas, coal, and, to a lesser degree, alternative fuels like wood chips and refuse. It is common to have multiple boilers as well as a backup fuel capability in any one central plant. Though variations exist, the typical hydronic (i.e., water-based) heating system distributes saturated steam (e.g., 100-120 psi), high temperature hot water (300-450 °F), or low temperature hot water (up to 250 °F). The hydronic heating medium is typically distributed through thermally insulated steel piping and also consists of similar associated return piping. The design type of the distribution piping system can be above ground (high or low profile), shallow concrete trench, direct-buried in conduits or casing, or direct-buried with walk-through “Utilidor” or “steam” tunnels, the former being used primarily in extreme cold climates. At each building being served, it is common for there to be a manhole or valve station where a smaller service line is connected to a main trunk line. For long buried runs, given the necessity for the piping to maintain a minimum slope, intermediate manholes without a building take off may be necessary where a reversal of slope is required. The return of the used and, hence, cooler hydronic medium usually involves pumping of either hot water or collected steam condensate. Various other appurtenances are associated with the differing system types and are critical for effective operation. Marsh et al. (1996) provided documentation on evaluations covering inspections of 35 heating distribution systems at 15 Department of Defense (DoD) and Department of Veterans Affairs installations.

Benefits

One of the original reasons for and benefits of these systems was to allow for relatively quick fuel switching at the central plant, especially in times of war. Presumably, during a protracted conflict, the intended switch would be to indigenous coal. Another benefit of central plants is the ability to limit air emissions and so avoid Notices of Violation at a small and fixed number of sources. Compared to the case of more, smaller, and distributed boilers, a central plant scheme also limits the overall amount of boiler maintenance that is needed. In addition, given the usual redundancy in the central plant, the reliability of service of these systems is usually extremely high.

Disadvantages

If these systems and their distribution piping are not maintained properly (unfortunately a common occurrence to varying degrees within the Army), it is possible to expend a significant amount of energy in the process of distributing the heat. A typical acceptable design value is a loss of 100 Btu/hr per lineal foot of distribution piping. If the insulation of the buried system has become wet or otherwise degraded thermally, the heat losses can be 5 or more times this value. If that same piping is in a flooded manhole where the drainage system has failed, a significantly greater amount of heat on a unit length basis will be lost. Another disadvantage for steam systems is the tendency to lose a significant portion of the returning condensate; losses in excess of 25 percent are not uncommon and systems losses less than 15 percent would be considered very good. Condensate loss requires a continuous need for replacement or “make up” which also entails costs in both treatment chemicals and avoidable energy input. Another disadvantage of centralized heating systems is that, on rare occasions when a main trunk supply line fails, it is possible to lose heat to a significant number of buildings on the system. Designing these systems in a loop configuration with an ability to back feed (or cross feed) is a common practice that largely alleviates this problem. Lack of maintenance of the system (including manholes) can also result in premature failure of the system. The distribution system itself is often the larger portion of the investment in the central heating system and premature failure of this component can make an otherwise economically attractive alternative completely the opposite.

Generic costs

In estimating the operating costs of centralized systems, it is worth emphasizing the multiple-fuels aspects. As the price of various fuels become more volatile while trending upward, it could be increasingly valuable to be able to frequently choose the lowest cost fuel per delivered unit of heat. Another aspect to consider is the possible implementation of a Cap-and-Trade system for carbon dioxide (CO_2) emissions within the United States. Currently in the European Union, under the Phase I Emissions Trading Scheme, an allowance for a ton of CO_2 cost € 20.00 – 30.00 (20 to 30 Euro), or more specifically, in April 2006, $38.70 (Thomson 2006). No such requirement exists in the United States. However, a number of non-coordinated CO_2 markets are being developed (e.g., Chicago Climate Exchange, Regional Greenhouse Gas Initiative, voluntary compliance markets, Kyoto Protocol Clean Development Mechanism). If such a requirement becomes U.S. law during the economic study period of the utility options being considered, then a centralized system could be favored in that CO_2 capture technology can more cost-effectively be applied to the fewer emission sources of centralized heating plants.

Alternatives for upgrades and refurbishments

The user faced with a significantly degraded or otherwise inefficient heat distribution system should evaluate the alternative of refurbishing or upgrading the system, as well as replacement or decentralization of heat supply. Above-ground piping systems are the easiest to refurbish or upgrade; for such systems it is a simple matter to correct any piping problems and replace or add thermal insulation. For piping in shallow concrete trenches, repairs and upgrades are also quite easy to accomplish. To a lesser degree, piping in buried tunnels repairs and refurbished/upgrades may be accomplished with modest effort. For all of these systems (above-ground, shallow concrete trenches, and buried tunnels), evaluation of the system condition is quite easy as well. For direct-buried systems, such as the common drainable, dryable, (pressure) testable (DDT) systems, assessing the condition of the buried portions of the system is much more difficult. While pressure testing of the conduit may reveal its integrity, it will not provide a measure of heat loss, which is the critical performance parameter. Fortunately, nondestructive infrared techniques provide a means to get reasonable estimates of heat loss (Phetteplace 1998, 2001; Phetteplace et al. 1998; Zinko et al. 1996). Surveys of the manholes on a heat distribution system can also reveal much about the condition of the systems within the manholes as well as provide clues to the condition of the buried piping between manholes/buildings.

When direct-buried DDT systems are found to be in poor condition, options for refurbishment are very limited. Systems to inject foam into the air space within the DDT system have been developed, yet the durability of these foams under long-term high temperature exposure has not been adequately established to the satisfaction of the authors. A low-cost alternative that might be considered on a site suitable for loose fill insulation, in accordance with UFGS-33 61 13, is to excavate the conduit, then cut and remove the top portion of the conduit. This allows inspection of the exterior of the carrier piping. If the carrier piping is in good condition, it can be insulated with appropriate insulation that has passed the Federal Agency boiling test and then the trench can be backfilled with an appropriate thickness of loose fill thermal insulation in the manner recommended by the loose fill insulation manufacturer.

Conversion to LTHW

Where the central heat distribution system is in poor condition and complete replacement is the only alternative, it is prudent to consider conversion to low-temperature hot water (LTHW) as the heat distribution medium. LTHW systems are discussed in this report, beginning on page 94.

Financing requirements

O&M projects deal with instances where existing parts have failed or are failing. These projects are funded by the installation using existing base O&M funds, which must be obligated within 1 year. If a failed or failing system is replaced by a system upgrade that costs up to $750,000,[9] the project can still be classified as O&M, rather than Military Construction, Army (MCA). MCA funds are for "new facilities" and require Congressional approval for authorization and funding of projects. The $750,000 ceiling specified in Section I of AR 415-15 (http://www.army.mil/usapa/epubs/pdf/r415_15.pdf) is for new, minor construction projects that make economic sense within the context of the O&M project. The amount spent on the O&M project is limited only by the size of the installation's O&M budget; however, no more than $750,000 may be spent on new or upgrade construction, regardless of the dollar size of the O&M project.

Full or partial decentralization of heating and/or cooling systems

General description

Decentralization involves the abandonment of central plants in favor of small, unattended boilers, water heaters, furnaces and/or small-scale cooling equipment installed at the individual buildings. Small decentralized boilers are, for the most part, gas-fired; these gas-fired boilers will need to be provided uninterruptible (firm) natural gas unless the site can permit the space to be unheated. In addition, a few electric boilers may be available to provide point-of-use hot water or steam. Figure C1 shows historical average natural gas prices from January 2001 to May 2006, courtesy of the Energy Information Administration (EIA 2006a).

[9] The $750,000 ceiling amount replaces the $500,000 amount in the previous version of AR 415-15.

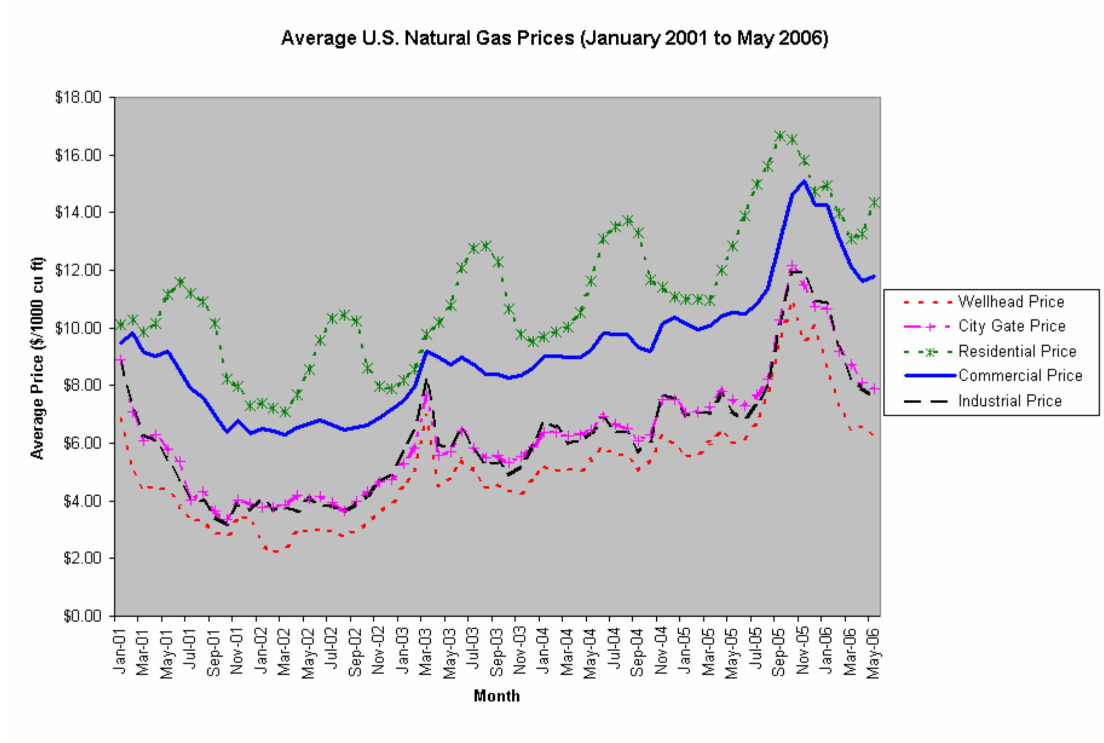


Figure C1. Average U.S. natural gas prices, January 2001 – May 2006.

Benefits

The higher costs of uninterruptible natural gas — at 30 to 40 percent more than the locally available interruptible gas supply — can be offset by the reduction in skilled labor costs and elimination of distribution system losses. Furthermore, there will be, in most cases, a larger pool of contractors qualified to operate and maintain smaller commercial-sized boilers than larger industrial-sized boilers (Brewer et al.).

Disadvantages

Maintenance is required on every boiler with at least one safety valve and fuel train, and 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 (Brewer et al. 1999). 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 (Brewer et al. 1999).

Generic costs

In determining the capital costs for decentralized systems, it is important to understand that the sum of the required peak building loads will be much greater than the sum of the building loads used in evaluating central systems, since central systems can capitalize on load diversity. A number of buildings will need to have redundant systems depending on the occupant's mission. The capital cost estimate for decentralized systems should include building, plant, or other system retrofit costs such as new gas lines, new heating, ventilating, and air-conditioning (HVAC) equipment, and electrical supply equipment. As with central systems, the annual O&M costs for decentralized systems should be estimated using component efficiencies and maintenance requirements for the selected equipment. The replacement cost should be estimated for all equipment expected to reach the end of its life cycle during the life-cycle analysis time frame. Building demand profiles can be used to calculate annual energy consumption (VanBlaricum et al. 1999).

Financing requirements and energy incentives for cost-effective implementation

Decentralization projects often use alternative financing mechanisms such as Energy Savings Performance Contracts (ESPCs) to achieve potential energy savings and measurement and verification of those savings. Examples of Army heating plant decentralization projects that utilize ESPCs include those at Fort Richardson, AK, and Picatinny Arsenal, NJ.

Low-temperature hot water heating distribution systems

General description

LTHW systems have been widely used in Europe for many years and are now gaining acceptance in the United States by the private sector. The low temperature materials and procedures have reduced the cost of these systems such that a cost advantage may be possible when replacing deteriorated steam and high temperature water systems. Many of the improved materials and methods used in the low temperature systems are not suitable for high temperature water or steam systems. Zhivov (2006) addresses the use of LTHW systems in Europe.

Benefits

Benefits of the LTHW systems include increased efficiency of heat distribution, reduced maintenance due to lower temperature and pressure, and improved materials that can be used only at these lower temperatures. Low temperatures and pressures also result in increased safety for service personnel and building occupants and better system control. Heat loss can be reduced from 20 percent or more for older systems, along with steam and high-temperature hot water (HTHW) systems, to under 5 percent of system capacity for LTHW systems. Field measurements by CRREL on new HTHW and LTHW systems have shown that the LTHW system lost only 35 percent as much heat. In addition, mass losses due to leakage can be reduced almost to zero, compared to make-up rates of 15 percent or more for good steam systems. For example, Phetteplace (1995) shows that the Hawthorne AAP, NV, steam system has a make-up rate of over 50 percent and a net thermal efficiency of less than 50 percent.

Disadvantages

The principal disadvantage of this technology is that it may require replacement of HTHW or steam piping systems where they exist, or construction of piping systems where no central system now exists. Construction costs for buried heat distribution systems are high (approximately $500 per foot) and are often an impediment to their use unless reasonably long lifetimes can be assumed. Building equipment that interfaces with the heat distribution systems may also need to be replaced when converting from steam/HTHW to LTHW.

Generic costs

Costs are highly variable depending on the site-specific factors and the size of the piping. The smallest diameter piping, flexible LTHW piping delivered on spools, is simply uncoiled into the open trench. Costs might be at around $100/ft all inclusive. For larger pipe diameters, direct-buried LTHW could range from $200 to $1000 or more per foot, depending again on the pipe diameter and the site-specific factors.

Implementation strategies

Because of the large capital investments required, the most favorable applications will be those where the existing system (central or otherwise) needs total replacement. Where an existing steam or HTHW distribution system exists, it may be possible to “phase” the conversion to LTHW to prolong the investment period and reduce supply interruptions. This phasing would be done by placing heat exchangers that generate LTHW from the HTHW or steam at the extremities of the network, eventually working back to the heat-generating plant to complete the system-wide conversion.

New central chilled water systems (satellite plants) or additions to existing systems

General description

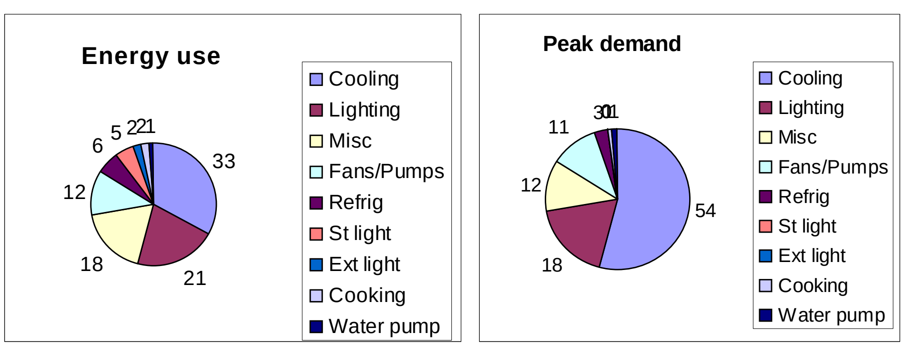
A recent draft Office of the Chief of Staff for Installation Management policy in consideration states, “A central cooling plant ... is the preferred option for an area or group of buildings (less than installation wide). Other options can be considered only if they meet the requirements of EPAct05 and a life-cycle cost analysis shows they are cost effective.” The underlying engineering principle is that a water-cooled centrifugal chiller is the most thermodynamically efficient system for production of cooling effect, and therefore is the most energy efficient cooling technology. Further discussion of energy efficiency in various cooling technologies is provided in Soo et al. (1997). A building or group of buildings with a total cooling load over 200 tons can be most efficiently cooled by centrifugal chiller(s) installed in a central cooling plant.

Benefits

For a typical Army installation, space cooling is the most significant contributor of electrical energy consumption as shown in Figure C2. Note also that space cooling accounts for more than half of the peak electrical demand. Implementation of the most energy efficient space cooling system will reduce the consumption of electrical energy (in KWH) as well as the peak demand (in KW).

Annual electricity use (KWH) and peak demand (KW) at Ft. Hood, TX

	Cooling	Lighting	Misc	Fans/Pum	Refrig	St light	Ext light	Cooking	Water pump
Energy	33	21	18	12	6	5	2	2	1
Demand	54	18	12	11	3	0	0	1	1



Reference:

Akbari, H., and S. Konopacki, *End-Use Energy Characterization and Conservation Potentials at DOD Facilities:* An Analysis of Electricity Use at Fort Hood, Texas, Lawrence Berkeley Laboratory, LBL-36974 UC-000, May 1995.

Figure C2. Categories of electrical energy consumption at Fort Hood, TX.

Benefits of central chilled water system based on a central cooling plant (for a building) or a satellite plant (for a group of buildings) include energy conservation (in KWH) as well as cost savings in the electrical demand charges.

The energy efficiency of a cooling system is represented by the KW/ton ratio. The KW/ton ratio for a water-cooled centrifugal chiller is as low as 0.3 KW/ton (typically 0.6 KW/ton) and that, for an air-cooled reciprocation chiller, is no less than 1.0 KW/ton (typically 1.2-1.5 KW/ton for old units). For a fixed amount of cooling delivered, the water-cooled centrifugal chiller consumes less than half the electrical energy compared to air-cooled reciprocating units typical for a small building.

Another benefit of a central cooling plant is that it can accommodate other cost-effective and energy efficient technologies (e.g., thermal storage, variable frequency drive pumping). With small air-cooled units for each individual building, it is difficult to take advantage of other cost-effective alternative cooling technologies.

Disadvantages

The main disadvantage of a water-cooled central cooling plant (compared to smaller air-cooled system for individual building cooling, e.g., scroll, reciprocating, and screw compressors) is the first cost, including the cost of a cooling tower. Routine maintenance of cooling tower may be contracted out to a local vendor if the Directorate of Public Works is not staffed with service technicians. The extra capital cost for a water-cooled central cooling plant with centrifugal chillers, however, is easily recoverable through the annual savings in electrical utility cost realized by the energy efficiency of the central chilled water system. The payback period depends on the local electrical utility rates, and would be typically within 5 to 10 years.

Generic costs

The installed cost of a typical central cooling system is given by $/ton, which includes the cost of the cooling tower. The system cost varies widely as a function of location. The location dictates the cooling load characteristics and the tower operating conditions. These factors in turn influence the system capacity. A significant portion of the installed cost is the contractor labor cost for installation. The required system capacity and the prevailing local wage scale at a given site make it difficult to produce a generic system cost. A recent study reports the installed system cost in the range of $200-

250/ton (Crowther and Furlong 2004). EPRI (1992) quoted the installed cost of water-cooled electric chiller package at $300–$550/ton. For a realistic cost estimate, contact a local contractor for a prevailing installed cost in $/ton for a particular locality.

Financing requirements and energy incentives for cost-effective implementation

For a new construction project, it is recommended that a group of small buildings (less than 100-ton cooling load each) be combined into a single block to be served by a central cooling plant. For a large building (over 200-ton cooling load), each building may have its own water-cooled central cooling plant or may be grouped into a block to be served by a common central cooling plant.

For a renovation project, a group of small buildings may be grouped into a block and a new central cooling plant can be installed to serve the block. Energy cost savings through improved energy efficiency of water-cooled centrifugal chiller(s) will make up the extra cost of a new satellite cooling plant. The energy cost savings can be calculated by the difference in the energy consumption between a new central plant and the aggregate total of individual air-cooled reciprocating units for each building. The payback period for the new plant will depend on the local electrical rate structure.

Cogeneration (combined heat and power – CHP)

General description

Cogeneration is the simultaneous production of usable heat and power in a single integrated thermodynamic process. Almost all cogeneration systems utilize hot air (exhaust gases) and steam for their process fluids. The final result is a system significantly more efficient than generating power and heat separately. Many CHP systems are capable of over 80 percent thermal efficiency.

Cogeneration systems are either *topping* and *bottoming*. In a topping system, electricity or mechanical power is produced first and the exhaust from the turbine is used for industrial processes, space heating, or other uses. The bottoming system reverses the order (i.e., power generation comes last).

Benefits

The benefits[10] of using cogeneration are the following:

1. Saves money
2. Higher efficiency, less environmental pollution, and lower fuel costs than generating heat and power separately. Figure C3 outlines the differences between the two systems.

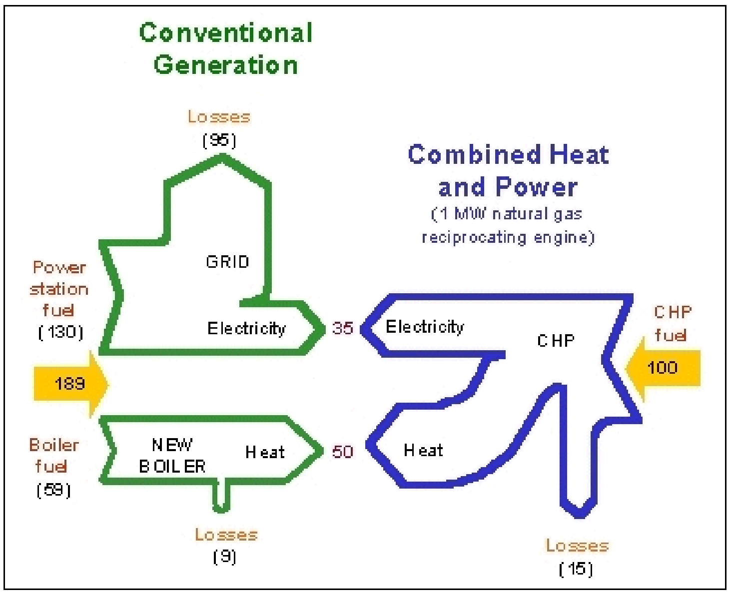


Figure C3. Comparison of systems based on 35 units of electricity and 50 units of heat needed.

(Source: U.S. Combined Heat and Power Association, http://uschpa.admgt.com/images/illust_chp.gif)

3. Improved energy security. Electricity is generated on-site; installations do not have to rely either on transmission or distribution lines from a local utility.
4. Location close to energy consumption
5. Lower transmission and distribution losses
6. Better power quality
7. Supports the grid infrastructure
8. Can facilitate the use of new energy technologies such as:
   a. Reciprocating engine
   b. Combustion turbine
   c. Steam turbine

[10] "CHP Basics & Benefits," Midwest Combined Heat and Power Application Center website, http://www.chpcentermw.org/03-00_chp.html.

d. Microturbine
e. Fuel cell
f. Combined-cycle.

Disadvantages

The disadvantages[11] of using cogeneration are the following:

1. No national standards exist for the interconnection of distributed generation technologies to the electric utility grid and, as a result, some utilities impose onerous and costly studies, and require the installation of unnecessarily expensive equipment to discourage CHP.
2. Many utilities charge discriminatory backup rates and prohibitive "exit fees" to customers that build CHP facilities.
3. Current regulations do not recognize the overall energy efficiency of CHP or credit the emissions avoided from displaced grid electricity generation.
4. Depreciation schedules for CHP investments vary from 5 to 39 years depending on system ownership, and frequently do not reflect the true economic lives of the equipment.
5. Many facility managers are unaware of technology developments that have expanded the potential for cost-effective CHP.
6. High first cost
7. Volatility of fuel prices
8. Complex interconnections
9. More O&M than a traditional heat plant
10. Heat distribution losses vs. decentralization (which does not have any losses)
11. Long lead-time for permitting issues
12. Large foot-print
13. Need to reside fairly near heat requirement for efficient heat distribution

Generic costs

Capital costs are a function of the following factors:

- Size of unit(s)
- Type of unit(s)
- Type(s) of fuels used
- Locality
- Size and type of pollution control devices

11 A portion of the information was obtained from U.S. Combined Heat and Power Association 2001.

- Permitting costs
- Decommissioning costs of old facility, if applicable

Example

The following example is courtesy of the Energy & Utilities Department, Naval Facilities Engineering Service Center, Port Hueneme, CA (NFESC undated).

Sizes available: 10 – 30 MW

Startup cost: $1,300 / kW (estimate)

Equipment life: 25 years

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

$$NES = Hydrocarbon\ Fuel\ Savings\ (in\ \frac{Btu}{yr}) +$$
$$(Electrical\ Energy\ Savings\ (in\ \frac{kWh}{yr}) \times$$
$$\frac{11{,}600\,Btu}{kWh}$$

ECONOMIC ANALYSIS EQUATION

SIR = (Fuel Cost) (DERF) + (Electric Cost) (DERF) - (Cogeneration Cost) (DERF) + ((O&M $_{Steam}$ *+ O&M* $_{Electric}$*) - O&M* $_{Cogen}$*) x (PYDF) / c (PIF)*

SAMPLE CALCULATION

Assumptions	
Size	10 MW (electricity) 100 MBtu (steam)
Annual fuel cost for incumbent steam plant	$4.911 M
Annual fuel cost for incumbent electric plant	$5.078 M
Annual O&M cost for incumbent steam plant	$0.232 M
Annual O&M cost for incumbent electric plant	$0.513 M
Startup Cost	$13 M
Fuels saved	Steam, electricity
Energy cost rate	$10/MBtu (steam) $0.08/kWh (electricity)
Escalation rate	8%, 7%
Annual discount rate ®	10%

Calculation follows from the procedure section:

Estimated steam savings = 0.18 x (Annual fuel cost for incumbent)

= 0.18 ($4,911 x 10^6 / yr) = $8.84 x 10^5 / yr

Estimated electric savings = 0.18 x (Annual fuel cost for incumbent)

= 0.18 ($5.078 x 10^6 / yr) = $9.14 x 10^5 / yr

Estimated O&M savings for cogeneration =

0.18 x (Annual O&M cost for incumbent steam) + 0.18 x (Annual O&M cost for incumbent electric)

= 0.18 ($0.232 x 10^6) + 0.18 ($0.513 x 10^6) = $4.18 x 10^4 + $9.2 x 10^4 = $1.38 x 10^5

FUEL SAVINGS (MBtu/yr)

Fuel Savings =

$$\frac{\text{Estimated Savings (\$ / yr)}}{\text{Cost of Steam (\$ / MBtu)}}$$

$$= \frac{\$8.84 \times 10^5 \text{ / yr}}{\$10 \text{ / MBtu}}$$

= 8,840 MBtu / yr

ELECTRICAL SAVINGS (kWh/yr)

Electrical Savings =

$$\frac{\text{Estimated Savings (\$ / yr)}}{\text{Cost of Electricity}}$$

$$= \frac{\$9.14 \times 10^5 \text{ / yr}}{\$0.08 \text{ / kWh}}$$

= 1.14×10^7 kWh / yr

NES (MBtu/yr) =

8,840 MBtu + (1.14×10^7 kWh / yr x 11,600 Btu / kWh) = 14,108 MBtu

FUEL COST SAVINGS ($ / yr)

Estimated Steam Savings = $0.884 M / yr

ELECTRICITY COST SAVINGS ($/YR)

Estimated electric savings = $0.914 M / yr

SAVINGS-TO-INVESTMENT RATIO CALCULATION

SIR =

$$\frac{\$0.884M(20.05) + \$0.914M(18.049) + \$0.138(PYDF)}{\$13M(1)}$$

$$= 2.7$$

Implementation Strategies

Market segments for cogeneration systems include (CEC 2004):

- Large and medium industrial systems – greater than 25 MW
- Small industrial system – 50 kW to 25 MW
- Smaller commercial and institutional systems – 25 kW+
- Residential – 1 kW to 25 kW

Table C1 provides an overview of metrics for implementing the cogeneration technology.

Table C1. Cogeneration metrics for implementation.

Combined Heat and Power Overview	
Commercially Available	Yes
Size Range	Several kW - 25 MW
Fuel	Depends on the availability
Efficiency	50-90%
Environmental	Reduces the use of excess fuel to produce heat.
Other Features	
Commercial Status	Selected systems commercially available.

Trigeneration

General description

Trigeneration is the simultaneous production of cooling, heating, and power (Trigeneration Technologies 2006) in one process.

A trigeneration plant is most often described as a cogeneration plant that has added absorption chillers. The chillers take the "waste heat" from a cogeneration plant and convert what would have been wasted by cogeneration into useful energy in the form of chilled water.

The trigeneration energy process produces four different forms of energy from the primary energy source – namely, hot water, steam, cooling (chilled water), and power generation (electrical energy).

Trigeneration has also been referred to as CHCP (combined heating, cooling and power generation); this option allows greater operational flexibility at sites with a demand for energy in the form of heating as well as cooling.

- *Heating and Power*: The heat and power portion of trigeneration is discussed in the earlier "Cogeneration" section.
- *Cooling*: In its simplest design the absorption machine consists of an evaporator, a condenser, an absorber, a generator and a solution pump. In a compression cycle chiller, cold is produced in the evaporator where the refrigerant or working medium is vaporized, and heat is rejected in the condenser where the refrigerant is condensed (TriGeMed).

The energy lifting heat from a low temperature to a higher temperature is supplied as mechanical energy to the compressor.

In an absorption cycle chiller (Figure C4), compressing the refrigerant vapor is effected by the absorber, the solution pump and the generator in combination, instead of a mechanical vapor compressor. Vapor generated in the evaporator is absorbed into a liquid absorbent in the absorber. The absorbent that has taken up refrigerant (spent or weak absorbent) is pumped to the generator where the refrigerant is released as a vapor, which is to be condensed in the condenser. The regenerated (strong) absorbent is then led back to the absorber to again pick up refrigerant vapor. Heat is supplied to the generator at a comparatively high temperature and rejected from the absorber at a comparatively low level, analogous to a heat engine.

Steam-fired units require 50-125 psi steam and about 10 lb/ton-hour steam usage. The higher the steam pressure, the lower the required pounds per ton usage.

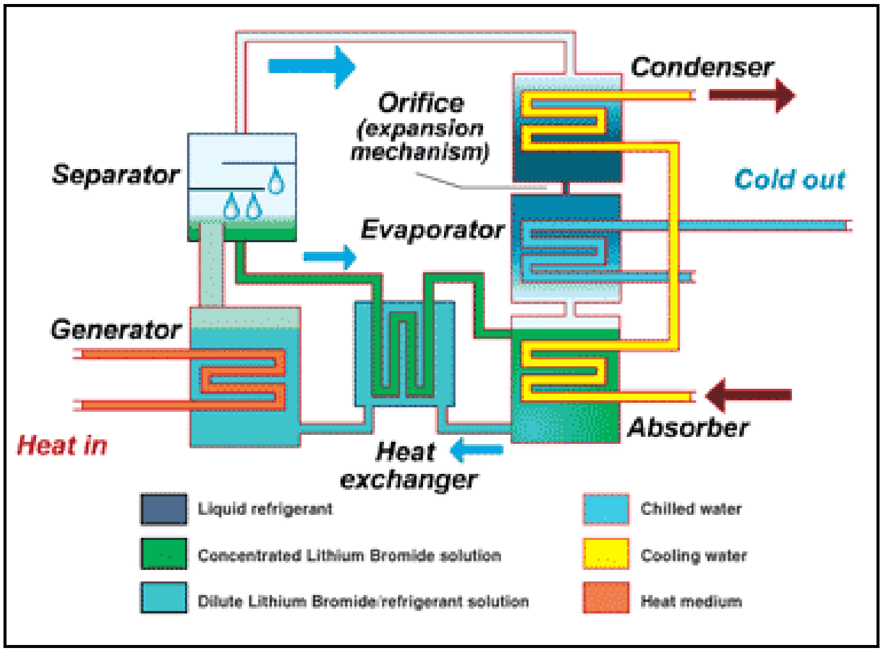


Figure C4. Absorption chiller cycle.

(Source: http://www.trigemed.com/images/icons/basic.gif)

Benefits

The benefits of using trigeneration are the following:

1. **Efficiency:** Trigeneration, when compared to (combined-cycle) cogeneration, may be up to 50 percent more efficient than cogeneration. When found in a hospital, university, office-campus, military base, downtown or group of office buildings, it has also been referred to as a "district energy system" or "integrated energy system." As previously mentioned, trigeneration can be dramatically more efficient and environmentally friendly than cogeneration.
2. **Fuel cuts:** The successful installation of CHP and CHCP leads to reduction of fuel consumption by approximately 25 percent compared with conventional electricity production.
3. **Emissions reduction:** The reduction of atmospheric pollution follows the same proportion. With the use of natural gas, rather than oil or coal, the emissions of sulfur dioxide and smoke are reduced to zero.
4. **Economic benefits:** The benefits for the user are economic. Energy costs of trigeneration units are lower than those of "conventional" units. In successful installations of CHP, the price reduction is in the range of 20-30 percent. It also improves employment at the local level.
5. **Increase in reliability of the energy supply:** The CHP station connected to the electric network, where it provides or absorbs electricity,

guarantees uninterrupted operation of the unit in case of interruption of the station's operation or electricity supply from the network. On a national level, it reduces the need to install large electric power stations and increases stability of the country's electric network.

6. **Increase of electricity network stability:** Trigeneration units offer significant relief to electricity networks during the hot summer months. Cooling loads are transferred from electricity to fossil fuel networks, since the cooling process changes from the widespread compression cycles to absorption ones. This transfer further increases stability of electricity networks and improves system efficiency, since summer peaks are served by electric companies through inefficient stand-by units and overloaded electricity transmission lines.
7. **Chlorofluorocarbons:** Absorbers use no chlorofluorocarbons or hydrochlorofluorocarbons, which are proven to damage the Earth's ozone layer.

Disadvantages

In addition to those disadvantages listed under "Cogeneration," the other disadvantages of using trigeneration are the following:

1. An early problem was "crystallization" where something would go wrong in the cycle and the salt and water would permanently separate, and the salt would crystallize on the walls of the absorber. Modern controls have virtually eliminated this problem.
2. Absorbers are large units, with on-site assembly required, especially in the larger tonnage units. However, the direct-fired units with the ability to both heat and cool from the same unit can take up less space overall than a boiler and separate electric chiller. Some units can optionally heat and cool at the same time (for multi-zoned applications that have both a heated and chilled water loop).
3. Absorbers must have a cooling tower; air cooled units are not an option, even for the smaller units.
4. All modern double-effect absorbers were developed in Japan; only recently, through partnerships, did American names start reappearing on units and very limited U.S. production began.
5. Chilled water temperature is at its lowest at about 46 °F. Therefore, absorbers cannot be used in a low-temperature refrigeration application.

Generic costs

Capital costs are a function of the following factors:

- Size of unit(s)
- Type of unit(s)
- Type(s) of fuels used
- Locality
- Size and type of pollution control devices
- Permitting costs
- Decommissioning costs of old facility, if applicable.

Thermal storage cooling system for demand-side management

General description

Thermal energy storage (TES) cooling system makes ice or chilled water during the utility off-peak period (typically during the night) and uses the stored ice or chilled water to provide cooling during the utility on-peak period (typically during the daytime). Generation of cooling effect with the off-peak electricity provides considerable savings in electrical utility cost for space cooling in Army installations. Amount of savings depends on the demand charge structure of the serving electrical utility. Typically, more than half of the billing peak demand is caused by the space cooling service. Again, typically half of the electrical bill for an Army installation is the demand charge except for the installations in the northern United States. Figure C4 shows the impact of space cooling on the electrical demand at Fort Hood, TX (Akbari andKonopacki 1995).

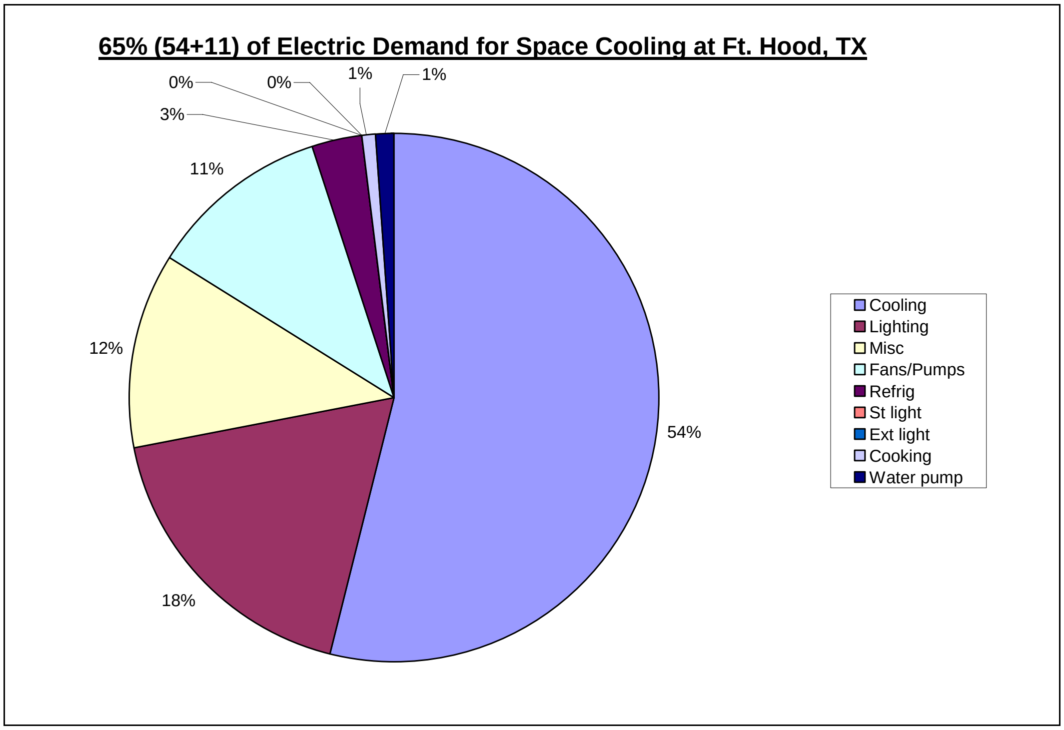


Figure C5. Components of electrical demand at Fort Hood, TX.

A difference between the conventional and TES cooling system is that the refrigeration unit is decoupled from the fan coil in TES as shown in Figure C6.

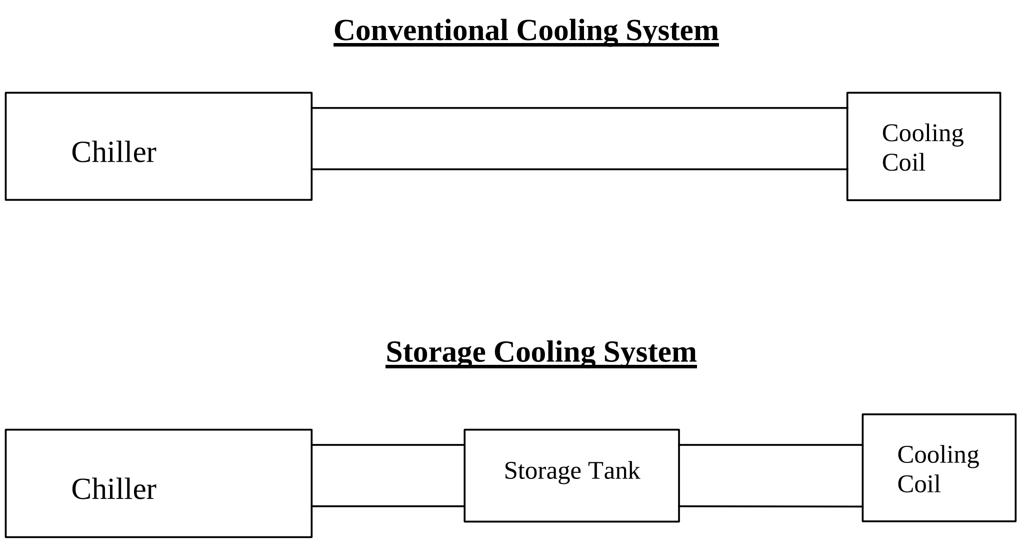


Figure C6. Schematics of conventional and TES cooling systems.

A typical TES uses water as the storage medium in the form of chilled water or ice in the storage tank. Most of the charge and discharge cycle is daily. Details of TES technology is covered by Dorgan and Elleson (1993) and Chapter 34 (Thermal Storage) in ASHRAE (2003). Currently, TES is mainly categorized into two types: chilled water storage and ice storage cooling systems. Table C2 compares the characteristics of each system.

Table C2. Comparison of ice and chilled water TES.

Characteristic	Ice	Chilled Water
Volume	Compact	Large
System	Modularized	Customized
Implementation	Factory built	Site built
Economy of scale	Low	High
Compressor derating	Severe (30%)	None
Energy penalty	Yes	None
Blending control	Simple	Need good design
Application	Single building	Central cooling plant

Ice is recommended as the storage medium for small-to-moderate sized systems (storage capacity less than 2,000 ton-hr). For larger systems with modular ice storage tanks, extended piping and flow balancing may require higher system capital costs as well as more maintenance. The energy penalty associated with ice making could be significant in larger systems. Due to the economy of scale, chilled water storage is not recommended for smaller systems with a storage capacity under 1,000 ton-hr unless free storage devices are available (EIRS 1993).

Benefits

Benefits of TES are listed in five categories: (1) Savings in electrical demand cost for space cooling, (2) Savings in energy cost with chilled water storage cooling, (3) Savings in capital cost with partial storage cooling system, (4) Back up emergency cooling capability, and (5) Savings in system capital cost or retrofit cost with cold air system. The demand cost savings are the predominant benefit among these categories. Each category of benefit is discussed below.

1. **Electrical demand cost savings**: The demand cost savings depend on the utility rate structure. As an example, Fort Jackson paid $5.3M for its electrical utility bill in 1996. The bill consisted of $2.6M for energy cost (based on KWH consumed) and $2.7M for demand cost (based on 23,424 kW of peak demand). By installing a 2.25M-gallon chilled water storage

tank (16,800 ton-hr capacity) to the Central Cooling Plant #2 at Fort Jackson, the peak demand was reduced by 3,450 kW at an electrical utility cost savings of $0.43M in 1997. Details of the Fort Jackson project are reported in Sohn et al. (1998). Another example of demand cost saving is an ice storage cooling system at Yuma Proving Ground (YPG), AZ. An ice storage tank with capacity of 1,050 ton-hr cooled a barracks complex of 86,100 sq ft. When the YPG system was installed in 1988, it saved $22,450/yr in electrical demand cost by shifting 173 kW from on-peak to off-peak periods. In 1998, YPG had negotiated favorable electrical rates with its utility supplier (Western Area Power Administration) by forming a partnership with the Welton-Mohawk Irrigation and Drainage District leveraging the load shifting capability of the YPG ice storage cooling system (Sohn and Nixon 2001).

2. **Energy cost savings**: For chilled water TES, chillers run during the night when the ambient temperature is lower than that during the day time. During the tank charging period, the chillers run under steady loading. Due to these favorable operating conditions (i.e., efficient cooling tower operation and steady chiller operation, energy efficiency of a chiller for a TES is expected to be higher than that of conventional chiller operation (Hensel et al. 1991). Note, however, that the energy efficiency of a TES is applicable only to chilled water storage cooling where the evaporator temperature remains the same between the TES and conventional chiller operation. For an ice storage cooling system, the TES consumes more energy due to the lower evaporator temperature required to freeze ice.
3. **Cooling system capital cost savings**: Potential capital cost savings could be achieved in two ways. One way is to utilize a partial storage system where the cooling plant capacity is down sized and the storage tank meets the remaining cooling load. In partial storage mode, the chiller runs both day and night providing cooling to the building and storing refrigeration effect when the building cooling load falls below the chiller capacity. The other case for capital cost saving is when the existing chiller plant needs extra capacity to meet the growing demand beyond the original design load. Adding a storage tank could be more cost effective than adding another chiller plant in terms of capital cost. A successful example is the New Mexico State University chilled water storage system discussed in Hensel et al. (1991).
4. **Back-up emergency cooling capability**: For a mission-critical facility (e.g., communication center, command and control post), a redundant cooling capability is mandatory to maintain the operating temperature of electronics equipment. A storage cooling system can provide continuous cooling in case of power failure with minimal power for operating the cir-

culation pumps. For a large TES with multiple chillers, the chiller plant can be designed without the N+1 design principle if a storage device is available. This will, in turn, help savings in the cooling plant capital cost.

5. **Savings in system capital cost or retrofit cost with cold air system**: This benefit can be possible only by ice storage cooling systems where the supply chilled water temperature could be lower than 42 °F of the conventional chilled water temperature. With lower supply temperature (i.e., higher delta T between supply and return temperatures), the sizes of the delivery system (water piping and air duct) can be reduced, thereby savings in the delivery system capital cost. A design guide for cold air system is available (Dorgan and Dorgan 1995), but the system design requires careful attention to take advantage of system features (e.g., insulation, diffuser).

Disadvantages

The primary objective of TES is savings in electrical demand cost by shifting the electrical demand from on-peak to off-peak periods. Therefore, TES is not economically feasible where the electrical demand charge is low. Disadvantages of TES are as follow:

1. **Storage tank is additional equipment**: As shown in Figure C6, TES requires a storage tank, which is additional equipment to a conventional cooling system. The cost of the tank should be less than the present worth of the life-cycle savings in the electrical demand cost for TES to be economically feasible. Note also that the tank requires space for installation.
2. **Ice storage cooling system consumes more energy compared to conventional cooling system for delivery of the same amount of cooling**. The energy penalty is due to lowered suction temperature of the compressor to freeze ice. The lowered suction temperature also affects the capacity of the compressor (i.e., derating of compressor from the capacity rating at typical chiller operating condition). Note that the energy penalty and the compressor derating apply only to ice TES. These limitations do not apply to chilled water TES, because the chiller evaporator temperature (and compressor suction temperature) for TES is the same as that of conventional cooling systems. For chilled water storage, a slight improvement in energy efficiency compared to conventional cooling system is possible as discussed in Benefits (page 110).
3. **Operator training is critical to realize benefits of TES**. Maintenance of storage tanks is extra, compared with conventional cooling systems. The maintenance requirement, however, is minimal due to the passive characteristics of the storage tank.

Generic costs

The cost of TES depends mainly on storage capacity and the type of storage media. For a typical feasibility analysis, the capital cost of TES is the cost differential between a TES and an equivalent conventional cooling system meeting the same cooling load. In new construction or scheduled replacement of an old cooling system, the extra cost for TES is mainly due to adding a storage tank. Discussion of the cost of TES for chilled water and ice storage follows:

1. Cost of chilled water storage: Chilled water storage tanks are site built and not available as a manufactured off-the-shelf item. Due to the economy of scale for construction of a tank, no chilled water storage tank below 0.25 million gallon storage capacity is recommended. The storage tank is built of concrete or steel. In either case, the cost of the storage tank is quoted in the range of $1.00 per gallon of storage with a strong economy of scale for a large capacity tank.
    a. The cost of a tank typically includes site preparation, tank construction, installation of diffuser system inside the tank, and circulation piping connected to the chiller plant.
    b. For a retrofit application, cost of circulation pumps and piping may not be included in the quote for the storage tank. It could be a separate cost item.
    c. The chiller plant does not need alteration to be coupled with a chilled water TES system. No extra cost in chiller plant modification should be expected.
    d. The required storage volume is about 100 gallons per each ton-hour storage capacity. Therefore, considerable space for the storage tank is required. For a typical Army installation, however, the cost of space is free if it is available.
2. Cost of ice storage: Ice storage tanks are typically manufactured by TES manufacturers according to their design specifications. The storage volume of ice TES is roughly one-seventh of that of chilled water storage. Since the ice storage tanks are modular in nature, the installation labor cost should be minimal. Due to the inherent energy penalty (see Disadvantage 2 above) of an ice TES, however, a large capacity (e.g., greater than 2000 ton-hour) ice TES is not recommended.
    a. The ice storage tank is typically available off-the-shelf based on the manufacturer's catalogue specifications. Cost of the tank should be discussed with the tank manufacturer.

b. For a retrofit application, confirm the existing chiller can produce ice (i.e., evaporator temperature lowered to 20 °F). If not, cost of the ice maker should be included in the TES cost estimating.
c. Cost of circulation pump and piping can be obtained from the typical mechanical costing guide (e.g., Means cost guide).
3. Feasibility: A TES cooling system is for electric demand cost savings, *not* for energy conservation. The payback period is determined by the expected annual savings in demand cost and the system first cost. Details on the methodology of feasibility analysis and cost factors are discussed by Sohn and Kim (1992).

Financing requirements and energy incentives for cost-effective implementation

Financial incentives for TES cooling systems may be available from the local electric utility company. Another form of incentive is a better rate negotiation based on the demand-side management capability of TES cooling systems as realized by YPG (Sohn and Nixon 2001).

The master meter for billing an Army installation offers a better payback opportunity for a TES cooling system compared to individual meters for each building in the private sector. The shift window from on-peak to off-peak in an Army installation can be significantly shorter than that of a typical commercial building. The shorter window makes TES application more cost effective in an Army installation. Any installation with a demand charge of more than $10/kW would be a good candidate for TES cooling system.

For a mission critical facility with back up cooling requirements, an ice storage TES cooling system could be cost effective. The cooling plant size can be significantly smaller, thereby resulting in less capital cost for the back-up cooling system. The most significant impact on the electrical utility cost savings will be realized by a large chilled water TES cooling system installed for a central cooling plant. For example, a 2.25M-gallon TES cooling system saves $0.43M per year in electric utility cost for Fort Jackson (Sohn et al. 1998).

Appendix D: Electrical Systems

Primary industry standards for electrical systems compliance

Among the primary industry standards recognized for electrical systems compliance are the following:

- National Electrical Manufacturers Association (NEMA) Standard TP1-2002, *Guide for Determining Energy Efficiency for Distribution Transformers*
- NEMA Standard TP2-2005, *Standard Test Method for Measuring the Energy Consumption of Distribution Transformers*
- Institute of Electrical and Electronics Engineers (IEEE) Standard 1547-2003, *IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*

Industry Standards Referenced in Unified Facilities Criteria on Electrical Systems

Unified Facilities Criteria (UFC) on power distribution systems (UFC 3-550-03N, *Power Distribution Systems*) can be obtained at the following website: http://www.wbdg.org/ccb/DOD/UFC/ufc_3_550_03n.pdf. UFC 3-550-03N, along with Army Technical Manual (TM) 5-811-1 (*Electrical Power Supply and Distribution*) and Military Handbook (MIL-HDBK) 1004/2A (*Power Distribution Systems*), references the following industry standards (with the most up-to-date versions cited by the latest year published), including, but not limited to:

- American National Standards Institute (ANSI) Standards:
  - ANSI C29.1-1988, *Test Methods for Electrical Power Insulators*
  - ANSI C57.12.01-1998, *General Requirements for Dry-Type Distribution and Power Transformers*
  - ANSI C57.96-1999, *Guide for Loading Dry-Type Distribution and Power Transformers*
- IEEE Standards:
  - ANSI/IEEE C2-2007, *National Electrical Safety Code*
  - ANSI/IEEE 18-2002, *Shunt Power Capacitors*
  - IEEE 141-1993, *Recommended Practice for Electric Power Distribution for Industrial Plants*

- IEEE 142-1991, *Recommended Practice for Grounding of Industrial and Commercial Power Systems*
- IEEE 242-2001, *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems*
- IEEE 979-1994, *Guide for Substation Fire Protection*

- NEMA Standard:
  - ANSI/NEMA CC 1-2005, *Electric Power Connection for Substations*
- National Fire Protection Association (NFPA) Standards:
  - NFPA 70-2005, *National Electrical Code*
  - NFPA 780-2004, *Lightning Protection Code*

Appendix E: Natural Gas Distribution Systems

Introduction

Natural gas distribution systems contain a network of pipes, pressure regulators, valves, meters, and other necessary accessories to distribute fuel gas (natural gas, manufactured gas, or liquefied petroleum gas) from the point of delivery by the gas supplier to the points of connection. Natural gas distribution systems are categorized into two types of pressure classes: *low-pressure* and *high-pressure*. Low-pressure natural gas distribution systems do not require service regulators on individual service lines that carry gas from the main, or supply source, to the customer's meter). High-pressure natural gas distribution systems, in which the system is operated at a pressure higher than the standard service pressure delivered to the consumer, require service regulators on each service line to control the pressure.

Availability of natural gas

Domestic natural gas production in the United States had reached its peak in 1973, but plateaued in 1980 due to massive exploration. The demand for domestic natural gas has exceeded its supply, with the United States importing 17 percent of the natural gas it consumes (Westervelt and Fournier 2005). According to the EIA, domestic natural gas production declined by 2.7 percent in 2005, mostly due to hurricanes damaging the infrastructure in the Gulf of Mexico. However, EIA further noted in the short term that dry natural gas production is projected to increase by 0.6 percent in 2006, with a 1.1 percent increase in 2007. In addition, net imports from liquefied natural gas are expected to increase from the 2005 level by 20.6 percent in 2006, with an additional increase of 31.6 percent in 2007 (EIA 2006a). The domestic natural gas proved reserve life is 8.4 years (Westervelt and Fournier 2005).

Industry standards related to natural gas distribution systems

International Fuel Gas Code

The *International Fuel Gas Code*, published by the International Code Council and the American Gas Association (AGA), specifies that choices for natural gas distribution piping be of the following materials:

- Steel and wrought-iron pipe, required to be at least of standard weight (Schedule 40) and in compliance with one of the following standards:
  - American Society of Mechanical Engineers (ASME) Standard B36.10-2004 (*Welded and Seamless Wrought Steel Pipe*);
  - American Society for Testing and Materials (ASTM) Standard A53/A53M-06 (*Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*); or
  - ASTM Standard A106/A106M-06 (*Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*).
- Plastic pipe in compliance with ASTM Standard D2513 (Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings).
- Aluminum-alloy pipe (except alloy 5456) in compliance with ASTM Standard B241/B241M-02 (*Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube*). (Note: Aluminum-alloy pipe is not to be used in exterior locations or underground.)

Threaded copper, brass, and aluminum-alloy pipe, as well as seamless copper, aluminum-alloy and steel tubing, are not to be used with gases corrosive to these materials, according to paragraphs 403.4 and 403.5 (ICC 2006).

The material choices for tubing (ICC 2006) are to be one of the following:

- Steel tubing in compliance with ASTM Standard A254-97(2002) (*Standard Specification for Copper-Brazed Steel Tubing*);
- Copper and brass tubing in compliance with one of the following standards:
  - Type K or L of ASTM Standard B88-03 (*Standard Specification for Seamless Copper Water Tube*); or
  - ASTM Standard B280-03 (*Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service*).
- Aluminum-alloy tubing in compliance with one of the following standards:
  - ASTM Standard B210-04 (*Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes*); or
  - ASTM B241/B241M-02 (*Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube*) (Note: According to subparagraph 403.5.3, as stated: "Aluminum-

alloy tubing shall be coated to protect against external corrosion where it is in contact with masonry, plaster, or insulation, or is subject to repeated wettings by such liquids as water, detergent, or sewage.”).

- Corrugated stainless steel tubing in compliance with ANSI Standard LC 1-2005/Canadian Standards Association Standard 6.26-2005 (*Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing*).
- Plastic tubing in compliance with ASTM Standard D2513 (*Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings*).

Paragraph 404.1 of the *International Fuel Gas Code* prohibits the installation of natural gas distribution system piping in or through circulating air ducts, clothes chutes, chimney or gas vents, ventilating ducts, dumbwaiters, and elevator shafts (ICC 2006).

In terms of above-ground, outdoor natural gas piping, paragraph 404.7 of the *International Fuel Gas Code* specifies the following guidance:

> Piping installed above ground, outdoors, and installed across the surface of roofs shall be securely supported and located where it will be protected from physical damage. Where passing through an outside wall, the piping shall also be protected against corrosion by coating or wrapping with an inert material (ICC 2006).

In terms of underground natural gas piping, paragraph 404.9 of the *International Fuel Gas Code* specifies the following guidance:

> Underground piping systems shall be installed a minimum depth of 12 inches (305 mm) below grade, [with the exception of individual outside appliances]... Individual lines to outside lights, grills, or other appliances shall be installed a minimum of 8 inches (203 mm) below finished grade, provided that such installation is approved and is installed in locations not susceptible to physical damage (ICC 2006).

Plastic pipe can be used only for outside underground natural gas distribution applications, with the following exceptions, according to paragraph 404.14 of the *International Fuel Gas Code* (ICC 2006):

- Plastic pipe shall be permitted to terminate above ground outside of buildings where installed in premanufactured, anodeless risers or service head adapter risers that are installed in accordance with the manufacturer's installation instructions.
- Plastic pipe shall be permitted to terminate with a wall head adapter within buildings where the plastic pipe is inserted in a piping material for fuel gas use in buildings.

Industry standards referenced in UFC on natural gas distribution

Unified Facilities Criteria on natural gas distribution (UFC 3-430-05FA, *Gas Distribution*) can be obtained at the following website: http://www.wbdg.org/ccb/DOD/UFC/ufc_3_430_05fa.pdf. According to paragraph 6*a* of UFC 3-430-05FA, plastic or steel pipe are preferred material choices for natural gas distribution system piping. According to paragraph 6*c* of UFC 3-430-05FA, plastic piping materials for natural gas distribution systems, whether used underground or as risers, should meet, as a minimum, the criteria established by Title 49, Code of Federal Regulations, Part 192 (49 CFR 192), ASTM standards specifications on plastic piping materials (e.g., ASTM D2513, ASTM D2517, and ASTM D3350), and the AGA *Plastic Pipe Manual for Gas Service* (UFC 3-430-05FA).

Modernization of natural gas system pipelines to industry standards

Guidance on cathodic and corrosion protection

All underground ferrous gas distribution piping requires cathodic protecttion, as mandated by paragraph 6*a* of UFC 3-430-05FA and Chapter 14, Section 4*b* of Corps of Engineers Technical Instruction 800-01, with cathodic protection design guidance on underground pipelines provided by TM 5-811-7.

Paragraph 404.8 of the *International Fuel Gas Code* specifies guidance on corrosion protection as follows:

> Metallic pipe or tubing exposed to corrosive action, such as soil condition or moisture, shall be protected in an approved manner. Zinc coatings (galvanizing)

shall not be deemed adequate protection for gas piping underground. Ferrous metal exposed in exterior locations shall be protected from corrosion in a manner satisfactory to the code official. Where dissimilar metals are joined underground, an insulating coupling or fitting shall be used. Piping shall not be laid in contact with cinders (ICC 2006).

Appendix F: Potable Water Systems

Industry standards referenced in Unified Facilities Criteria on potable water systems

Unified Facilities Criteria on potable water systems (UFC 3-440-02N, *Water Conservation Operation and Maintenance*) can be obtained at the following website: http://www.wbdg.org/ccb/DOD/UFC/ufc_3_440_02n.pdf. UFC 3-440-02N references the following industry manuals and standards (with the most up-to-date versions cited by the latest year published), including, but not limited to:

- American Water Works Association (AWWA) Manuals and Standards:
  - AWWA Manual M6, *Water Meters - Selection, Installation, Testing, and Maintenance*
  - AWWA Manual M22, *Sizing Water Service Lines and Meters*
  - AWWA Manual M36, *Water Audits and Leak Detection*
  - AWWA Standard C700-02, *Cold-Water Meters -- Displacement Type, Bronze Main Case*
  - AWWA Standard C701-02, *Cold-Water Meters—Turbine Type, for Customer Service*
  - AWWA Standard C702-01, *Cold-Water Meters—Compound Type*
  - AWWA Standard C703-96 (R04), *Cold-Water Meters—Fire Service Type*
  - AWWA Standard C704-02, *Propeller-Type Meters for Waterworks Applications*
  - AWWA Standard C706-96 (R05), *Direct-Reading, Remote-Registration Systems for Cold-Water Meters*
  - AWWA Standard C707-05, *Encoder-Type Remote-Registration Systems for Cold-Water Meters*

Appendix G: Wastewater Systems

Industry standards related to wastewater treatment systems

Wastewater treatment system design for Army and other military installations is governed by Military Handbook (MIL-HDBK) 1005/16 (*Wastewater Treatment Systems Augmenting Handbook*, January 2004) under the Unified Facilities Criteria. This handbook supplements the set of commercial design documents adopted by the military for use in designing wastewater treatment facilities at military installations and is the handbook used for this chapter unless otherwise indicated. That primary design set consists of six manuals of practice (MOPs) published by the Water Environment Federation (WEF). The manuals are:

- *Design of Municipal Wastewater Treatment Plants*, MOP 8, Jointly published with the American Society of Civil Engineers (ASCE)
- *Gravity Sanitary Sewer Design and Construction*, MOP FD-5, Jointly published with ASCE
- *Design of Wastewater and Stormwater Pumping Stations*, MOP FD-4
- *Alternative Sewer Systems*, MOP FD-12
- *Existing Sewer Evaluation and Rehabilitation*, MOP FD-6, Jointly published with ASCE
- *Wastewater Disinfection*, MOP FD-10

Additional guidance is available through the “10-State Standards” (Great Lakes-Upper Mississippi River Board and State Public Health and Environment Managers) and the specific design manuals for military Corps of Engineer Districts which have responsibility for design of wastewater treatment systems.

MIL-HDBK-1005/16 is a process design guide and does not address general plant design. In designing and constructing any wastewater treatment facility, numerous design details need to be considered. They include water supply systems, lighting requirements, service buildings and equipment, landscaping, and proprietary processes and equipment. Requirements for these design elements are given in other military and service-specific publications.

Design personnel should also check current service policy documents for detailed instruction. Service-specific directives take precedence over information contained in the Military Handbook. Facility fencing and security guidance is provided in MIL-HDBK-1013/1, *Design Guidelines for Physical Security of Fixed Land-Based Facilities* and MIL-HDBK-1013/10, *Design Guidelines for Security Fencing, Gates, Barriers, and Guard Facilities*.

Where discrepancies exist between the WEF manuals and MIL-HDBK-1005/16, the information in the Military Handbook takes precedence and should be used. MIL-HDBK-1005/16 replaces MIL-HDBK-1005/8 (*Domestic Wastewater Control*, TM 5-814-3), which has been inactivated but is available for reference on past projects.

A number of topics outside the detailed design of wastewater treatment systems must be addressed prior to design. WEF MOP 8 contains general facility planning and design development guidance for such areas as project sequencing and design standards, procurement alternatives. It defines objectives in the first two chapters.

Other topics which merit discussion include:

1. A review of regulatory compliance and management issues for addressing permitting needs and defining the level of treatment required.
2. Facility planning activities, including the need to conduct engineering studies prior to design to establish the need for new or modified facilities, to develop the deign basis for those facilities, and to determine the most efficient alternative for achieving the objectives based on cost and non-cost criteria.
3. Additional planning and budgeting activities that should be part of the design, such as the need for site-specific O&M manuals, facility start-up training, and facility performance testing.
4. General design guidance regarding beneficial reuse of solids, wastewater reuse, and considerations for cold climate design.

Additional requirements for planning and commissioning of wastewater treatment plants are included in MIL-HDBK-353, *Planning and Commissioning Wastewater Treatment Plants*.

Regulatory compliance

Federally owned treatment works

Generally, federally owned treatment works (FOTWs) are operated and administered under similar permitting and operational provisions set forth for publicly owned treatment works. These facilities comply with the construction permitting, operational permitting, and effluent discharge and residuals handling permitting requirements as administered by individual states and/or the USEPA.

Permitting requirements

Permits are issued for the construction or modifications of FOTWs, discharge of treated effluent, discharge of stormwater runoff, and residual solids management practices. These permits can be issued by Federal (USEPA), state, or local governments. Sometimes all three levels of government issue separate permits. More often, the FOTW operating permits are combined.

The National Pollutant Discharge Elimination System (NPDES) program issues NPDES operating permits required before an FOTW can discharge any process water into waters of the state. The majority of states have “primacy,” meaning they operate the program and are authorized to issue those permits. States may also incorporate their own requirements into the permit. In some states, separate permits are required by state and federal entities plus any local requirements. In addition to wastewater, NPDES permits can also address stormwater and solids.

An NPDES permit is not a construction permit. In some jurisdictions, an owner may construct or modify a facility, but it is a violation to operate the modified facility until a valid operating permit is obtained. Other states limit all construction activities until the changes or modifications are approved. Any change or modification to the process should be reviewed with the permitting agency prior to implementation to determine if a permit modification is required.

Stormwater NPDES Permit

In accordance with 40 CFR 122.26, stormwater associated with industrial activities is managed under a separate stormwater NPDES program. FOTWs that treat more than 1 million gallons per day are included in the stormwater NPDES permitting program as a categorical industrial facility.

Most facilities obtain a general stormwater NPDES permit. This permit is maintained separately from the other permit and requires special reporting and applications. Construction of wastewater treatment plants over 5 acres in area will also require a stormwater construction permit, although that area may be smaller for a given state.

Residual Solids Permit

FOTW residual solids management has received special attention under CFR 40 Part 503. Solids management will typically be addressed as part of the FOTW operating permit, although a separate permit may be required.

Permit renewal

NPDES permits are valid for up to 5 years. Permit renewal applications must be submitted 180 days before the expiration date. Preparation for the application begins about 1 year before the permit application is due. Preparation involves assessing plant performance and improvement need and conducting the necessary planning and design required to keep the facility in compliance. This review should be documented in a Capacity Analysis Report and an O&M Report, both of which are described as #1 and #2, respectively, under "Facilities planning" below.

Governing effluent limitations

In planning any wastewater treatment facility, it is essential that the specific set of effluent limitations the facility will be required to meet is defined at the start of the planning process. Potential new requirements for effluent limitations should also be identified so they can be considered in the planning and design of the facility.

Current trends in the wastewater industry that affect effluent permitting

The regulatory agencies responsible for the issuance of discharge permits are implementing more comprehensive programs to ensure protection of the water quality standards of the state's streams. In addition, the regulatory agencies are implementing basinwide permitting programs designed to bring into compliance those streams identified as not currently meeting water quality standards. The program evaluates all sources of pollution (point and nonpoint sources) through the development of total maximum daily loads for the watershed. The program allocates allowable discharge levels for all sources within the drainage basin. This could mean more restrictive effluent limits in the future.

Effluent limits contained in the NPDES permit are developed by the permit writer and are normally based on state water quality standards for the receiving stream. The inclusion of water quality-based effluents in the permit is based on a review of the effluent characterization presented in the discharger's permit application. Most NPDES permits include limits on oxygen-demanding substances (such as carbonaceous biochemical oxygen demand [CBOD] and ammonia). Development of these limits is typically based on a waste load allocation for the receiving stream. Stream modeling is used to assess the assimilative capacity of the stream based on the applicable dissolved oxygen standard. Water quality-based effluents can be based on chemical-specific criteria from the water quality standards or on general narrative criteria. Specific criteria are used to develop effluent limits, and in many cases an allowance for dilution in the receiving stream is provided. Background concentrations in the receiving stream must also be considered in these calculations.

Wastewater effluent toxicity

Effluent limits to minimize the toxic effects of discharges on aquatic life are increasingly being added to NPDES permits. These limits can apply to specific aquatic life or can contain general criteria to limits toxicity.

Wastewater reuse

Two general categories of wastewater management exist: wastewater disposal and wastewater reuse. Several states and communities have, for decades, been promoting the beneficial reuse of wastewater as a way of reducing both water demands and wastewater disposal to the environment. Wastewater treated to appropriate standards and reused is often referred to as reclaimed water. The most common reuse projects involve the use of reclaimed water for irrigation purposes (e.g., golf course, commercial, and residential). Other uses include fire protection, landscape features, and industrial supply (e.g., cooling).

Design requirements for cold climates

Some military installations are in areas of extreme cold, including arctic and subarctic regions. Because extreme cold significantly affects the design and operation of wastewater facilities, special considerations are required when facilities are to be located in these conditions. Detailed information on cold weather design is presented in TM 5-852-1/AFR 88-19, Volume 1, *Arctic and Subarctic Construction General Provisions*. Additional information is provided in an ASCE (1996) monograph.

The effects of extreme cold on wastewater facilities can be grouped into three categories:

1. **Construction**. Because of soil conditions such as permafrost, special considerations should be given to the construction of facilities, particularly for collection systems. Alternatives include above-ground pipelines and combined utility systems called "utilidors."
2. **Freezing**. Many of the normal components of wastewater facilities, such as influent screening, grit removal, and primary treatment, are subject to freezing in extremely cold regions. These facilities will typically need to be enclosed or covered, and above-ground tanks may require insulation. Design biological processes such as lagoons and ponds to withstand the effect of ice, and use submerged aeration systems.
3. **Processes**. Both chemical and biological processes are negatively affected by extreme cold. Chemical reaction rates are generally slower at low temperatures and chemical solubilities are reduced. The rates of biological processes are also reduced greatly. The biological processes that have been used most successfully in cold climates include lagoons or ponds, either facultative or aerated, activated sludge with long solids retention times, and attached growth systems that are adequately enclosed and protected from the cold.

In addition to the direct effects of cold on the design and operation of wastewater facilities, wastewater characteristics will generally differ from those in temperate regions. Wastewater in arctic and subarctic regions typically will be primarily domestic in nature and higher in strength than at comparable facilities in other regions.

Facilities planning

MIL-HDBK-353 describes the planning required for precommissioning a wastewater treatment facility. The sections below describe reports to be prepared as part of the facilities planning process.

1. <u>Capacity Analysis Report</u>. This report documents the predicted future flows and loads within the treatment facility, and evaluates the capacity of existing unit processes to reliably treat those loads for the next permitting cycle. The historical flows and the treatment performance of the previous 5 years need to be analyzed. The CBOD and total suspended solids loading

(in pounds per day) also need to be verified. Populations and flow and load projections are then made to estimate future loads, based on projected growth from changing or expanded missions. The capacity of each unit process needs to be determined. Reliability and backup provisions must also be adequate. An assessment of the future 5-year flow and loads needs to be conducted. If the plant is undersized, an expansion needs to be initiated and a Preliminary Engineering report for improvements developed. Higher discharge loads will also precipitate additional permit application requirements to address antidegradation issues.

2. Operation and Maintenance Report. This report reviews plant operation data over the last permit cycle to evaluate needed improvements to the facility. Any upsets or spills need to be reviewed to determine the cause and possible solution.
3. Programming. MIL-HDBK-353 describes programming requirements for planning and commissioning wastewater facilities. A Requirements and Management Plan (RAMP) must be finalized prior to designing a project. Engineer Technical Letter 95-2, *Preparation of Requirements and Management Plan Packages for Military Construction (MILCON) Program Projects*, provides guidance on preparation of RAMP packages.
4. Preliminary Engineering Report. After a RAMP is finalized, a Preliminary Engineering Report should be prepared. The Preliminary Engineering Report will outline what changes are required to attain or maintain compliance. Typically, this report will contain a summary of the future flows and loads to be treated, a review of any alternative evaluations used to select the appropriate treatment technologies, and a conceptual-level design for upgraded facilities. The Preliminary Engineering Report should include, as a minimum, the information discussed in the following paragraphs.
5. Design Basis. Present the design basis for the proposed wastewater facilities, including the following:
    a. **Service Area Description**. Define the area and users to be served by the proposed facilities.
    b. **Projected Flows and Loads**. Summarize wastewater flows and loads to be handled by the proposed facilities. Identify major industrial and other significant discharges. In general, provide flows in 5-year increments over the planning period for the facilities. A 20-year plan should normally be used for evaluating wastewater facilities.
    c. **Effluent Requirements**. Provide tentative effluent limitations based on review of regulatory requirements and discussions with the governing regulatory agency. Potential future changes to the effluent limitations should also be discussed.

d. **Residuals Solids Handling Requirements**. Provide anticipated disposal methods for residual solids and associated regulatory requirements.
e. **Other Regulatory Requirements**. Identify other regulatory requirements that may affect the facility's evaluation and design, including reliability requirements, air pollution standards, noise ordinances, and hazardous material storage and handling requirements.

6. Alternatives Evaluations. In general, alternatives evaluations should be performed to determine the facility configuration and processes that will most cost effectively meet the requirements identified in the design basis. Evaluate alternatives for liquid treatment processes to meet effluent limitations and solids treatment processes for handling and disposing of residuals. When evaluating liquids treatment processes, consider how the processes will affect the quantity and characteristics of residuals. In addition, recycle flows from solids handling and treatment processes can significantly affect liquids treatment processes and should be evaluated.
7. Life-Cycle Costs Evaluation. This section is explained in more detail in Chapter 4 under "Wastewater Systems" (page 42).
8. Nonmonetary Evaluation. Alternatives should also be evaluated using nonmonetary criteria, which should be established with input from key personnel responsible for the construction and operation of the proposed facilities. This evaluation is largely subjective and should be done with participation of key personnel. Among the nonmonetary criteria are:

- Operability
  - Ease of operation
  - Ease of maintenance
  - Operator familiarity
- Reliability
  - Demonstrated performance
  - Hydraulic sensitivity
  - Waste loading sensitivity
  - Process control stability
  - Flexibility
- Environmental Effects
  - Odor
  - Noise
  - Visual impacts
  - Effects on floodplain
  - Effects on wetlands
  - Footprint

- Expandability
    - Footprint
    - Flexibility

9. Recommended Plan. Following the alternatives evaluation and selection the recommended plan will be described. This will consist of a conceptual design and should include the following:
    a. Process design criteria and preliminary sizing of process facilities and equipment
    b. Preliminary hydraulic profile based on the peak design flow
    c. Preliminary mass balance for plant showing process performance and residuals production based on design loadings
    d. Site layout showing location of major facilities
    e. Preliminary layouts for major process facilities
    f. Overall electrical feed and distribution plan
    g. Overall instrumentation and control plan indicating the type of system proposed and major process control and monitoring functions
    h. Specific provisions to meet other regulatory requirements such as stormwater drainage and treatment.

Appendix H: Proven, Energy-Efficient, and Cost-Effective Technologies

Ground-source heat pumps

General description

Heat normally flows from a warmer medium to a colder one. This basic physical law cannot be reversed without the addition of energy. A heat pump is a device that does so by essentially "pumping" heat up the temperature scale transferring it from a cold material to a warmer one by adding energy, usually in the form of electricity. A heat pump functions by using a refrigerant cycle similar to the household refrigerator. In the heating mode, a heat pump removes the heat from a low temperature source, such as the ground or air, and supplies that heat to a higher temperature sink, such as the heated interior of a building. In the cooling mode, the process is reversed so that the heat is extracted from the cooler inside air and rejected to the warmer outdoor air or other heat sink. For space conditioning of buildings, heat pumps that remove heat from outdoor air in the heating mode and reject it to outdoor air in the cooling mode are common. These are normally called air-source or air-to-air heat pumps. A normal window-type air-conditioner works in the same way as an air-to-air heat pump, except it cannot be reversed to provide heating. Ground-source heat pumps (GSHPs) use the ground, ground water, or surface water as a heat source or sink.

Different terms used to describe GSHP systems include: Geothermal Heat Pumps, Earth Source Heat Pumps, Geo-source Heat Pumps, and Geo-exchange systems. All systems that embody the ground-source concepts described below have been lumped into the general category of GSHPs here. Primarily for marketing reasons, other names, such as those above, will be found in use. A brief summary of the types of GSHP systems is included below. For a more detailed discussion see Phetteplace (2002).

Types of Ground-Source Heat Pumps

The three basic types of GSHPs are ground-coupled heat pumps (GCHPs), ground water heat pumps (GWHPs), and surface water heat pumps (SWHPs). Each of these GSHPs is described in more detail below.

Ground-coupled systems

GCHPs use buried closed-piping loops that exchange heat with the ground to "couple" the heat pump systems with the ground. This process of heat exchange is accomplished by circulating a fluid, usually water or a water-based antifreeze solution, in buried pipe loops. The buried pipe loops consist of either vertical (Figure H1) or horizontal (Figure H2) arrays of buried special purpose "plastic" pipe that form heat exchangers with the ground. Vertical heat exchangers are fabricated simply by drilling boreholes into the ground and inserting a "u-tube" into the borehole. This type of drilling often does not require drilling equipment or techniques as elaborate as those used for normal water well drilling. In addition to low land-area requirements, vertical ground coupling has several other advantages: stable deep soil temperatures with greater potential for heat exchange with ground water, and adaptability to most sites. Disadvantages of vertical ground-coupling are potentially higher cost, problems in some geological formations, and the need for an experienced driller/installer.

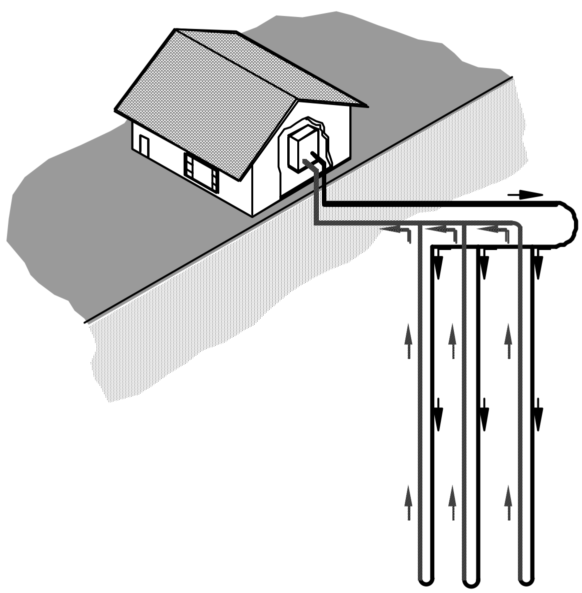


Figure H1. Vertical ground-coupled system.

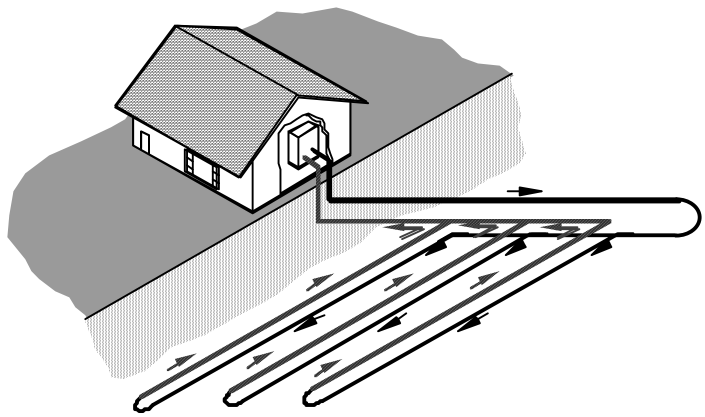


Figure H2. Horizontal ground coupled system.

Horizontal heat exchangers may be installed in trenches excavated by trenching machines, backhoes, or excavators. Piping may be placed in the trenches either singly or in multiple-pipe arrangements. The primary advantage of horizontal systems is lower cost. This advantage results primarily from fewer requirements for special skills and equipment combined with less uncertainty in subsurface site conditions. The disadvantages of horizontal ground-coupling are its high land-area requirements, its limited potential for heat exchange with the groundwater, and the wider temperature swings of the soil at the typical burial depths.

An alternate method of installing a horizontal heat exchanger is the "slinky" method (Figure H3). When using the slinky method, a wide pit is excavated with a bulldozer, excavator, backhoe, or loader. The coils of plastic piping, rather than being uncoiled, are spread out in a spiral pattern resembling a deformed slinky toy. Usually a fixture is used to obtain uniform coil spacing before the coils are tied to one another to maintain the appropriate spacing. The material excavated is then carefully pushed or placed back over the piping coils. It is also possible to use the slinky method with the coiled placed vertically in trenches. Obtaining adequate compaction of the backfill can be difficult for the vertical slinky configuration. Slinky systems have the same advantages as conventional horizontal systems but require less land area and are adaptable to a wider range of construction equipment. In general, the most favorable means of heat exchanger construction will depend on local soil conditions and the type of construction equipment available.

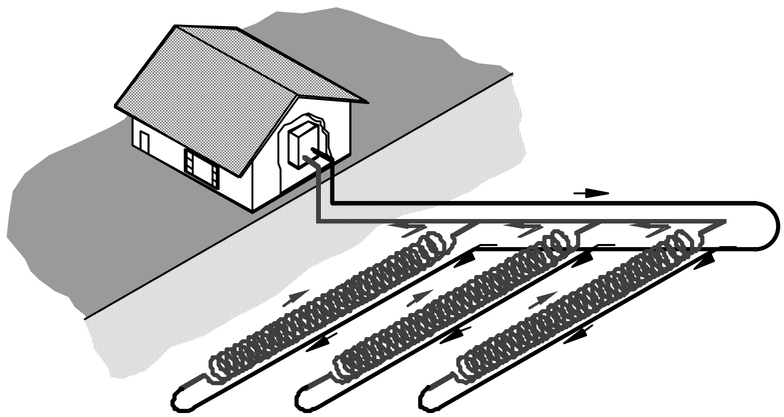


Figure H3. Horizontal slinky ground-coupled system.

Ground-water systems

GWHP systems are the oldest form of GSHPs. These systems extract water from the ground, exchange heat with this water, and then return it to the ground (Figure H4) or dispose of it at the surface (Figure H5) where permitted. These systems have the lowest installed cost in most cases, especially in larger applications. However, their use is limited by the availability of ground water. For larger applications, water quality is not as much of an issue as one might imagine as heat exchangers are used to isolate the heat pumps from the ground water. By isolating the heat pumps from the ground water it becomes possible to provide a central heat exchanger for an entire building, normally of the plate and frame type, that may be easily cleaned as necessary. Avoiding contact between the ground water and the atmosphere (i.e., oxygen) is paramount to eliminating problems with GWHP systems. Failure to recognize this fact and to provide an isolating heat exchanger led to the premature failure of many early GWHP systems.

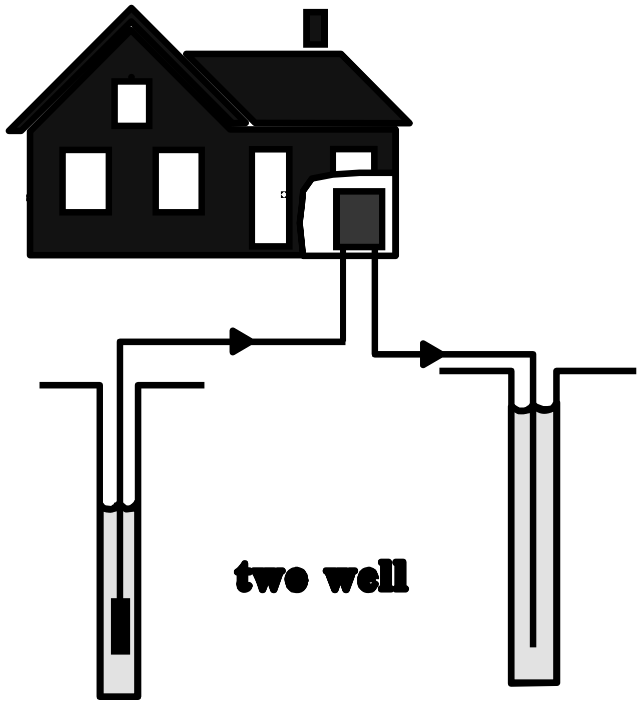


Figure H4. Ground water heat pump systems with supply and re-injection wells.

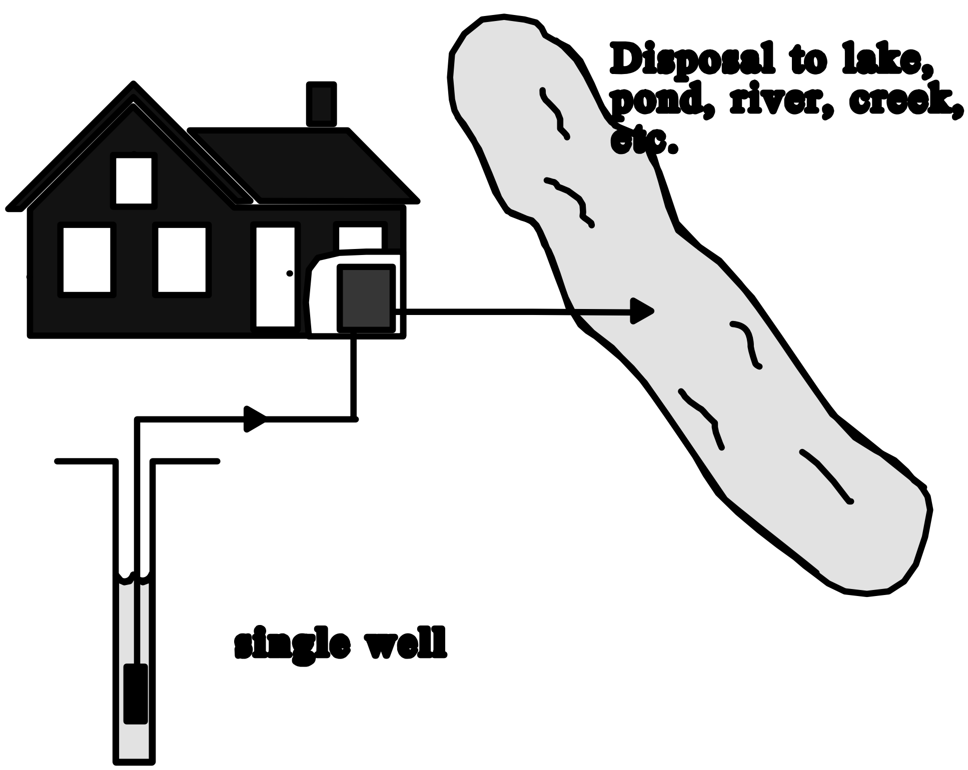


Figure H5. Ground water heat pump systems with disposal at surface.

Surface-water systems

SWHP systems extract or discharge heat to surface water bodies. In some instances, this may be done directly by piping water from the water body to and from the heat pump (Figure H6) while, in other instances, it is done by “coupling,” again using plastic pipes, submersed in the water body (Figure H7).

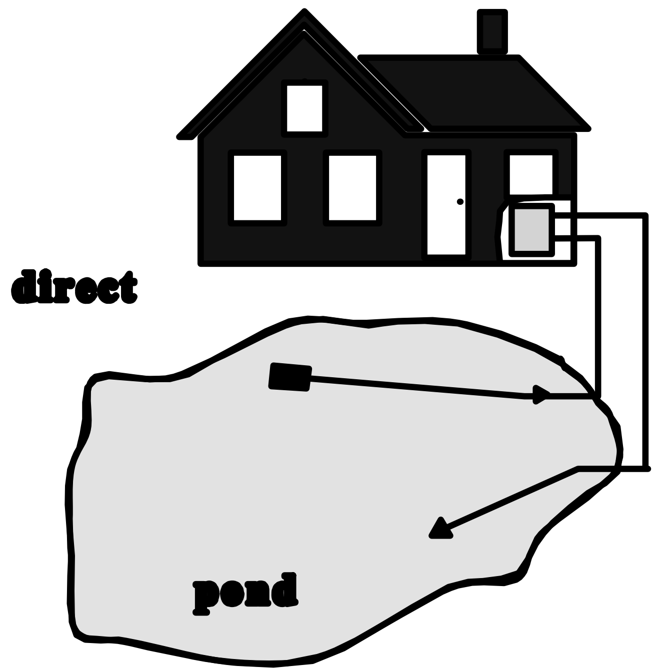


Figure H6. Surface water heat pump system.

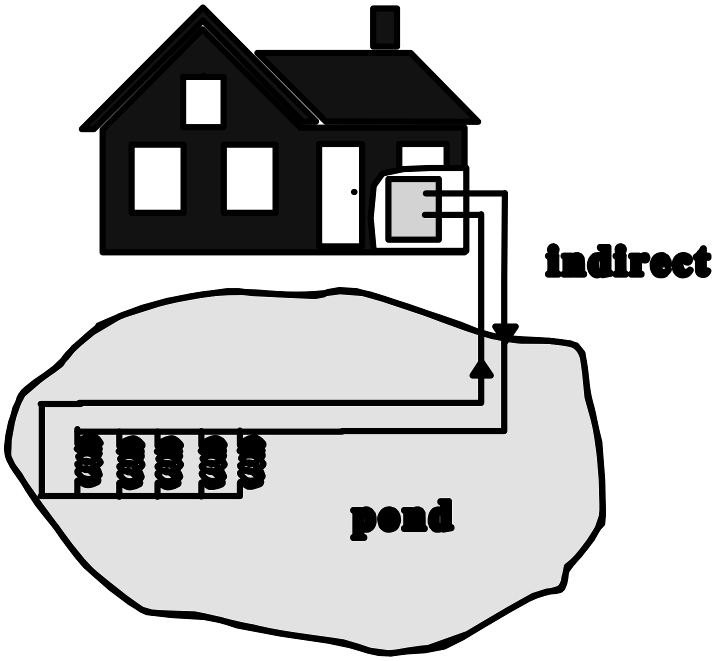


Figure H7. Surface water system with indirect coupling.

Benefits

For residential-scale (family housing) applications, GSHPs will often offer significant reductions in energy consumption (and attendant cost). The configuration and indoor space requirements of the equipment are not significantly different than other HVAC equipment for residential scale. The absence of any outdoor condenser unit is a distinct advantage from both the maintenance and "vandalism" viewpoints. The absence of any need for a fossil fuel source offers increased safety as well as environmental benefits.

For larger, commercial-scale applications, GSHPs have a number of advantages compared to conventional equipment such as variable air volume systems. With individual heat pumps serving each zone, control and comfort are superior to many other types of systems using large central equipment. This ideal zone control coupled with the unitary design of the equipment results in simple but highly reliable systems that can be maintained without the need for special skills. Operating costs for these systems tend to be lower than for conventional equipment, especially when all the parasitic losses of large central systems are considered. The heat pumps themselves, like the related technology of the household refrigerator, tend to be very reliable with low maintenance and long lifetimes. GSHP systems require no on-site fuel storage and are considered a green technology with no on-site, unregulated emissions. Finally, because the equipment is distributed around the building, mechanical room space requirements are greatly reduced or, in some cases, eliminated altogether.

Disadvantages

For both residential-scale and commercial-scale uses, the primary disadvantage of GSHPs is that they tend to have higher initial costs than some conventional systems. In commercial applications, however, they are often able to compete favorably on a first-cost basis against some of the more costly conventional systems (i.e., four-pipe systems), but will normally be at a cost disadvantage when compared, for example, to rooftop equipment. In many applications, any additional initial investment will be quickly returned in reduced operating and maintenance costs.

Another disadvantage of GSHPs is that their application is site-specific. At a few Department of Defense (DoD) facilities in the continental United States, some type of a GSHP would not be technically feasible, but in a significant number of instances, GSHP installation would not be economically viable. In addition, in some areas local regulations may essentially preclude some or nearly all types of GSHP systems. Where that is not the case feasibility becomes a question of economics. Economics are driven by the capital cost and operating costs of both the GSHP alternatives and the "conventional" system alternatives.

Generic costs

Capital cost for a conventional system is largely determined by installed capacity, a parameter that is easily determined in the process of conventional building design, or in retrofit cases may be known based on existing equipment if properly sized. GCHP system design is unlike most other HVAC design in that peak load is only one of the questions that need to be answered. It is of paramount importance that the design of the ground coupling be executed properly, as it is usually a major portion of the total GCHP system cost, and oversizing will often render a project economically unattractive. Alternately, undersizing is normally difficult to correct after construction is complete and will normally result in increased operational costs and possibly even HVAC system failure.

Sizing of the ground loop requires that the aggregate "block" loads and their distribution and duration be known. This requirement stems from the realities of the heat exchange with the ground; the ability of the ground to act as a heat source or sink is inextricably determined by the history of heat extraction/rejection from it. For all but the most northern climates, commercial-scale buildings will have significantly more heat rejection than extraction. This imbalance in heat rejection/extraction can cause heat buildup in the ground to the point where heat pump performance is adversely affected and hence system efficiency and possibly occupant comfort suffer. Proper design for commercial-scale systems almost always requires the use of computer-aided design (CAD) software. CAD software for commercial-scale GCHP design should consider the interaction of adjacent loops and predict the potential for long-term heat buildup in the soil. See Sanner et al. (1999) for a discussion of available CAD programs. Two of the more widely used CAD packages available for this purpose are GCHPCalc (Energy Information Services Co.) and GLHE Pro (International Ground-Source Heat Pumps Association), both of which are approved by Unified Facilities Guide Specification 23 81 47.

The local infrastructure is a critical factor in determining costs and thus feasibility. In some regions, the lack of GSHP infrastructure, both with respect to design and construction, can be a disadvantage impossible for GSHP systems to overcome. In those areas where GSHPs have not seen much development to date, it may be difficult to locate experienced designers and installers. In many cases, however, it is possible (and well advised) to procure these services from outside the area at competitive prices, especially when a large installation is being made.

Implementation strategies

DoD has successfully implemented a number of GSHP systems through both normal military construction channels and other mechanisms such as “Shared Savings” arrangements. Some fairly significant shortcomings have also occurred in some installations. Because the ground-coupling is always a major portion, if not the largest fraction of the capital costs, the temptation always exists to try and reduce the amount of ground-coupling used. This reduction is at odds with achieving a fully functional design that will deliver the expected energy savings. Because performance can degrade with time when ground coupling is inadequate, it is imperative that savings be based on metered data, not projections. This is also true since the performance of the units in the first instance is a function of the effectiveness of the ground-coupling as well as many aspects of the loading, so it cannot be assumed based manufacture’s ratings or results achieved in other installations.

Distributed Generation Technologies

General description

Distributed generation is defined as “small amounts of generation located on a utility's distribution system for the purpose of meeting local (substation level) peak loads and/or displacing the need to build additional (or upgrade) local distribution lines” (CEC). Distributed generation technologies include *reciprocating engines, microturbines, combustion gas turbines, fuel cells, photovoltaics,* and *wind turbines.*

Types of distributed generation technologies

This section addresses those distributed generation technologies that apply to systems external to the buildings and are applicable for determining options for modernizing utility systems. Fuel cells and microturbines will be discussed in greater detail in this section. Photovoltaics and wind turbines are covered later in this Appendix under “Renewable energy technologies.”

Fuel cells

Fuel cells convert a fuel’s chemical energy directly into electrical energy with high efficiency. Fuel cells electrochemically combine a fuel (such as hydrogen) and an oxidant (such as oxygen) without burning. The four principal components of a fuel cell system are as follows (UC-Irvine):

1. The *fuel cell stack,* in which a fuel is fed through a negatively-charged electrode (called the anode), enabling electrons to be stripped from the fuel to flow through an external circuit, while the positive ions travel through an electrolyte to the positively-charged electrode (called the cathode) to combine with oxygen ions and the free electrons to produce water in the form of steam;
2. The *reformer*, or fuel processor, which extracts hydrogen-rich gas from the fuel — whether by steam reforming, partial oxidation, or gasification — emitting carbon dioxide and trace amounts of carbon monoxide;
3. The *electric power conversion device,* which converts the direct current (DC) electricity produced by the fuel cell into alternating current (AC) electricity; and
4. The *balance of plant,* which refers to supporting and/or auxiliary components based on the power source.

Fuel cells come in six primary types:

- *alkaline fuel cells*, which were the first types of fuel cells used for manned space applications and contain a potassium hydroxide solution as the electrolyte;
- *molten carbonate fuel cells*, which use as an electrolyte either an alkali carbonate (sodium, potassium, or lithium salts) or a combination of alkali carbonates retained in a ceramic matrix of lithium aluminum oxide;
- *phosphoric acid fuel cells*, which use a concentrated 100 percent phosphoric acid electrolyte retained on a silicon carbide matrix;
- *proton exchange membrane (PEM) fuel cells*, which contain an electrolyte that is a layer of solid polymer allowing protons to be transmitted from one face to the other;
- *solid oxide fuel cells*, which use as an electrolyte a nonporous metal oxide; and
- *direct-methanol fuel cells*, which use a polymer membrane as an electrolyte (UC-Irvine).

Applications for using fuel cell technology are listed as follows:

1. **Stationary:** Stationary fuel cells range from 5 kW to 40 MW and are applied in residential and commercial power units, combined heat and power, premium power, and uninterruptible power supplies. Proton exchange membrane, molten carbonate, phosphoric acid, and solid oxide are typical types of fuel cells used in stationary applications.
2. **Mobile:** Mobile fuel cells range from 25 to 150 kW and are applied in light- and medium-duty vehicles, buses, industrial trucks, and naval and submarine vessels. Proton exchange membrane and direct methanol fuel cells are typical types of fuel cells used in mobile applications.
3. **Portable:** Portable fuel cells range from 1 to 50 kW and are applied in wheelchairs, golf carts, truck and rail refrigeration units, road signs, space vehicles, and satellites. Proton exchange membrane, alkaline, and direct methanol fuel cells are typical types of fuel cells used in portable applications.
4. **Micro:** Fuel cells used in micro-applications range from 1 to 500 W and are applied in cell phones, personal digital assistants, notebook computers, portable electronics, and selective military hardware. Direct methanol fuel cells are typical types of fuel cells used in micro-applications (Texas SECO).

The American Council for an Energy-Efficient Economy (ACEEE) provides a listing of fuel cell manufacturers at http://www.aceee.org/chp/fuelcell-list.html.

Microturbines

The microturbine technology has been derived from automotive and truck turbochargers, auxiliary power units for airplanes, and small jet engines used on pilotless military aircraft. The *compressor*, *combustor*, *turbine*, and *generator* comprise the primary components of the microturbine (DOE 2006c). Most microturbine designs are single-shaft and use a high-speed permanent magnet generator producing variable voltage and variable-frequency AC power (Resource Dynamics Corporation 2001).

The key component of the microturbine is the *recuperator*, an air-to-heat exchanger that transfers heat from the exhaust gas to air that is sent to the combustor. Preheating the combustor inlet air reduces the fuel consumption of the microturbine, thereby increasing its overall efficiency. Microturbines can provide high operating efficiencies of 25 to 30 percent. In addition, high-temperature recuperator materials (e.g., ceramics) can improve efficiency levels by allowing microturbines to operate at higher temperatures. Relatively low inlet temperatures of 1,600 °F and high air-to-fuel ratios in the combustor section enable microturbines to keep their nitrogen oxide (NO_x) emissions under 10 parts per million (Valenti 2000).

Microturbines can be used for stand-by power, power quality and reliability, peak shaving, and cogeneration applications. Microturbines are also utilized in resource recovery and landfill gas applications. They have the capability to produce between 25 and 500 kW of power, and are therefore compatible for applications at small commercial building establishments, such as restaurants, hotels/motels, small offices, and retail stores (CEC 2002d).

Benefits

Fuel cells

Fuel cells provide the following benefits:

- Because fuel cells are electrochemical devices, they are not limited to Carnot efficiencies. Consequently, some fuel cells can achieve electrical efficiencies as high as 50 to 60 percent, and overall efficiencies greater than 85 percent.

- Fuel cells also have very low emissions. Water and heat are the only emissions of a fuel cell operating on pure hydrogen and pure oxygen. Fuel cells that operate on fossil fuels (natural gas, propane, etc.) have much lower emissions than a conventional fossil fuel combustion device.

Microturbines

Microturbines provide the following benefits:

- Microturbines have fewer moving parts than reciprocating engines, resulting in the potential for longer lives with reduced maintenance.
- Microturbines offer lower emissions than comparably sized reciprocating engines.
- Microturbines use pressurized natural gas, air compressors, and recuperators in order to achieve high operating efficiencies.
- The fuel flexibility of microturbines allows a variety of potential applications, ranging from distributed generation and cogeneration when using natural gas, to transportation applications when using gasoline or diesel fuel.
- Microturbines have extremely low NO_x emissions and noise levels.

Disadvantages

Fuel cells

Fuel cells provide the following disadvantages (DOE 2006k):

- The cost of fuel cell power systems must be reduced before these systems can compete with conventional technologies.
- Fuel cell systems do not have an established durability. In terms of the reliability of stationary fuel cell systems, more than 40,000 hours of reliable operation in a temperature range of at -31 to 104 °F (-35 to 40 °C) will be required for market acceptance.
- The low operating temperature of PEM fuel cells restricts the amount of heat that can be effectively utilized in CHP applications. Consideration should be made in developing technologies that will enable higher operating temperatures and/or more effective heat recovery systems and improved system designs that will facilitate CHP efficiencies to exceed 80 percent. In addition, technologies that allow cooling to be provided from the low heat rejected from stationary fuel cell systems (such

as through regenerating desiccants in a desiccant cooling cycle) should also be considered.

Microturbines

Among the disadvantages for using microturbines are the following (RDC 1999):

- Despite projected decreases in installed costs, first cost remains a barrier.
- Technological advances have lowered the size threshold for economically viable power generation equipment.
- Industry and business owners have a limited understanding of the range of benefits associated with microturbines and other micropower technologies.

Generic costs

Fuel cells

The capital costs of fuel cells range from $3,500-$10,000/kW (depending upon size, power output, performance, fuel type, etc.), with the installation costs of fuel cells typically about 30 percent of the capital cost (CEC 2002a). The total installation cost is based on the following: the defined power generation module, the power conditioning unit, balance of plant equipment, installation, general facilities and engineering fees, project and process contingencies, and owner costs. Average O&M costs for fuel cells are in the range of $0.005-$0.01/kW (CEC 2002c). Based on a 25-MW gross capacity and a 20-year economic life, the levelized costs of electricity by fuel cell technology, using natural gas, are $0.21/kWh for phosphoric acid fuel cells, $0.13/kWh for solid oxide fuel cells, and $0.10/kWh for molten carbonate fuel cells (CEC 2004c).

Microturbines

The capital costs of microturbines range from $700-$1,100/kW. A 30-kW microturbine has a typical installation cost of $1,000/kW, which is nearly 100 percent of the maximum capital cost for a microturbine of similar capacity (CEC 2002a). Average maintenance costs for microturbines range from $0.05/kWh to approximately $1.60/kWh, based on maintenance required every 5,000 to 8,000 operating hours (CEC 2002a). The total cost of electricity would be equal to the summation of the capital cost, installation cost, O&M cost, and fuel cost (CEC 2002b). The cost of electricity may be affected by additional economic factors such as utility stand-by charge, net metering, incentives or rebates, and energy-efficiency credits (CEC 2004a).

Financing requirements and energy incentives for cost-effective implementation

A listing of federal and state-by-state energy incentives for implementing distributed generation technologies is documented in greater detail in Tables H3 and H4 at the end of this Appendix.

Renewable energy technologies

General description

Renewable energy is defined by Title II, Section 203 of the EPAct05 as "electric energy generated from solar, wind, biomass, landfill gas, ocean (including tidal, wave, current, and thermal), geothermal, municipal solid waste, or new hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project." In accordance with Initiative #3 of the *Army Energy and Water Campaign Plan for Installations*, on-site renewable projects are expected to be life-cycle cost-effective to justify implementation. These on-site renewable projects developed on or near Army installations are to meet or exceed the following levels by the specified fiscal years:

- Short range: 1 to 5 percent of total electricity consumption by FY10
- Mid-range: 5 to 10 percent of total electricity consumption by FY15
- Long range: 10 to 15 percent of total electricity consumption by FY30

Types of Renewable Energy Technologies

This section addresses those renewable energy technologies that apply to systems external to the buildings and are applicable for determining options for modernizing utility systems.

Biomass (including wood)

Biomass can be used to provide heat, make fuels, and generate electricity. The types of biomass include wood, plants, residue from agriculture or forestry, and the organic component of municipal and industrial wastes. Biomass resources in the future may be replenished through the cultivation of fast-growing trees and grasses called *biomass feedstocks* (DOE 2006a).

While biomass can be converted directly into liquid fuels such as ethanol and biodiesel for transportation needs, biomass is also applicable in facilities that generate electricity. The heat from biomass can be used to convert it to a fuel oil that can be burned like petroleum to generate electricity. Additionally, biomass can be burned directly to produce steam for electricity production or manufacturing processes. In the case of a power plant, a turbine captures the steam, and a generator converts that steam into electricity. In the lumber and paper industries, wood scraps are often directly fed into boilers to produce steam for their manufacturing processes or to heat their buildings. Biomass is also often used at certain coal-fired power plants as a supplementary energy source in high-efficiency boilers to reduce emissions. Gasification systems use high temperatures to convert biomass into a gas – a mixture of hydrogen, carbon monoxide, and methane. The gas, in turn, fuels a turbine, which turns an electric generator.

The decay of biomass in landfills additionally produces methane gas, which can be burned in a boiler to produce steam for electricity generation or for industrial processes. The next section describes landfill gas in more detail.

Landfill gas

As solid waste is decomposed in a landfill, landfill gas is created. Landfill gas is about 50 percent methane — the primary component of natural gas — and the remainder is CO_2 and nonmethane organic compounds. Landfill gas has about half the heat content of natural gas (i.e., about 500 Btu per standard cubic foot) and burns at a lower temperature than natural gas due to the larger volume of nitrogen, CO_2, and moisture contained in landfill gas.

Landfill gas can be captured, converted, and used as an energy source. The extraction of landfill gas from landfills is accomplished by using a series of wells and a blower/flare (or vacuum) system, which directs the collected gas to a central location where it can be processed or treated depending upon the use of the fuel (USEPA 2006b).

Among the types of landfill gas-to-energy conversion (USEPA 2006b) are as follows:

- **Electricity generation**: Electricity for on-site use or sale to the electrical grid can be generated using internal combustion (reciprocating) engines or turbines, with microturbine technology used at smaller landfills. Emerging technologies include Stirling (external combustion) engines, Organic Rankine Cycle engines, and fuel cells.
- **Direct-use**: Direct use of landfill gas to offset the use of another fuel (i.e., natural gas, coal, fuel oil) is appropriate in boiler, dryer, kiln, greenhouse, and other thermal applications. Wastewater treatment industries currently use landfill gas.
- **Cogeneration**: Cogeneration projects using landfill gas generate both thermal and electric energy, typically in the form of steam and water.
- **Alternate fuels**: Landfill gas has been delivered to the natural gas pipeline system as both a high-Btu and a medium-Btu fuel.

According to the USEPA's Landfill Methane Outreach Program (LMOP), the most typical boiler technology suitable for retrofitting for landfill gas is the packaged boiler, which is of two common types: *water-wall packaged boilers*, used in larger capacity, high-pressure applications, and *fire-tube packaged boilers*, used in smaller capacity, low-pressure applications. Retrofitting the boilers with dual fuel burners that can utilize natural gas as a back-up fuel can result in fuel constancy and flame stability. Table H1 provides a list of boiler retrofit challenges for converting to landfill gas and suggested solutions to overcome those challenges (USEPA 2001).

Table H1. Boiler retrofitting challenges for conversion to landfill gas.

Challenges in Converting to Landfill Gas	Solutions
Greater volume of gas flow	Use larger orifices on fuel control valves.
Flame stability	Equip ultraviolet sensors with redundant scanners.
	Employ dual fuel burners.
Lower flame temperature	Increase superheater size.
Corrosion	Insulate preheater and flue stack.
	Preheat combustion air with steam coils.
	Ensure that water circulation meets manufacturer's specifications.
Deposits	Remove deposits during routine maintenance.

Photovoltaics

Photovoltaic (PV) materials and devices convert light energy into electrical energy. PV cells, also termed solar cells, are made of semiconductor materials that produce electricity. The PV cells are connected together to form modules, and groups of modules can be combined to form PV arrays of different sizes and power output. The size of a PV array depends upon certain factors, such as the amount of sunlight available in a particular location and the needs of the consumer. Three types of materials used for PV cells are: silicon (whether single-crystalline, multi-crystalline, or amorphous), polycrystalline thin film, and single-crystalline thin film. Figure H8 shows a cross-section of a PV cell.

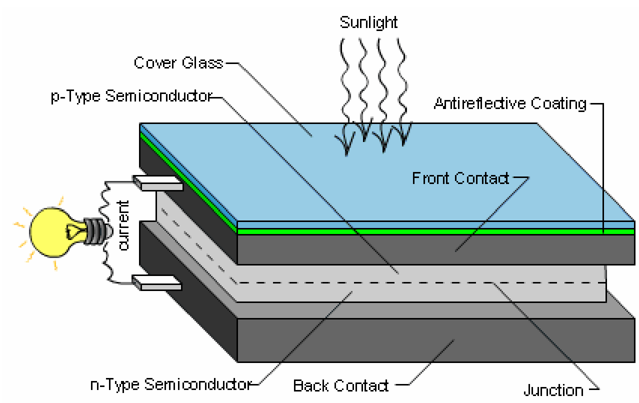


Figure H8. Cross-section of a PV cell.

(Source: http://www.energy.ca.gov/distgen/equipment/images/photovoltaics.gif)

PV systems are categorized into two types: *flat-plate PV systems*, which use panels that can either be fixed in place or allowed to track the movement of the sun, and *concentrator PV systems*, which use plastic lenses and metal housings to capture the solar energy shining on a large area and focus that energy onto a smaller area, where the solar cell is. Wiles et al. (undated) provides an assessment of satisfactory and unsatisfactory PV technology installations.

Applications for using the PV technology are listed as follows:

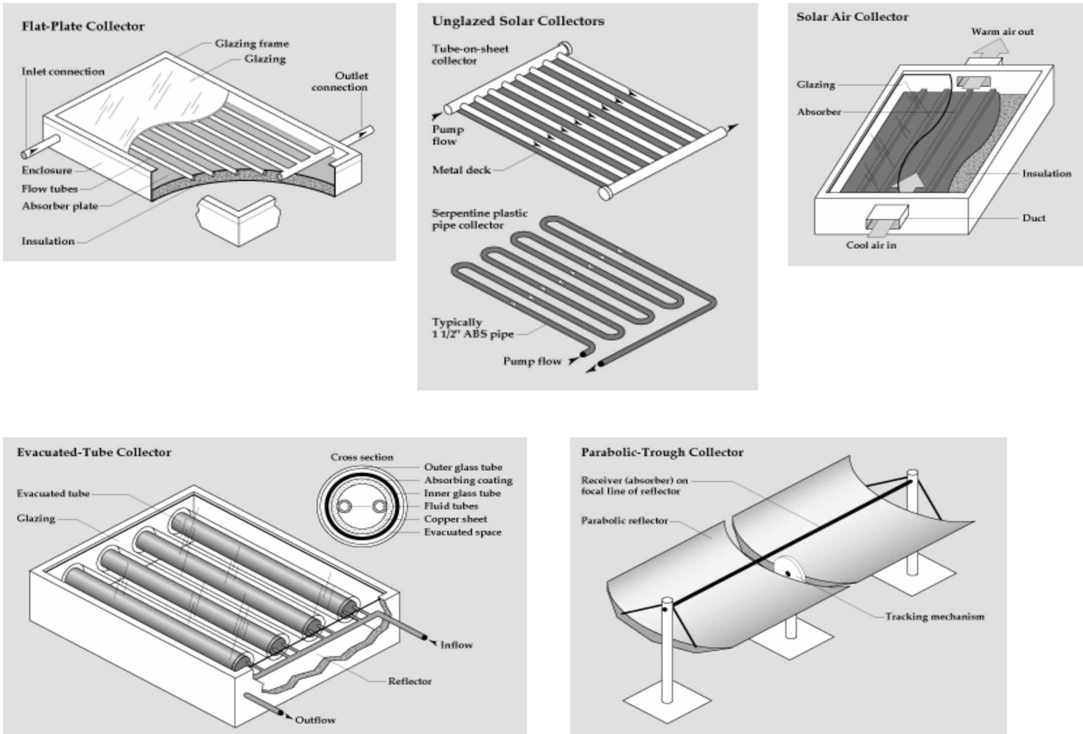
1. **Stand-alone PV systems:** Stand-alone PV systems are most applicable in locations where utility-generated power is unavailable, undesirable, or too costly to hook up to. The electricity generated by these stand-alone PV systems can be used to power water pumps, ventilation fans, and other appliances that use DC electricity.

2. **PV systems with battery storage:** PV systems with batteries for storage are useful in areas where utility power is unavailable or due to cases where the cost of utility line extensions is expensive. PV systems with battery storage can be designed to power equipment requiring AC or DC electricity.
3. **PV systems with generators:** During the day, daytime energy needs are quietly supplied by PV systems, and the batteries are charged. If the batteries run low, the engine generator runs at full power until the batteries are charged. Engine generators can serve as a viable backup for PV modules at night or on cloudy days.
4. **Hybrid power systems using PV:** Hybrid power systems combine electricity production and storage equipment (namely PV, engine generators, wind generators, small hydroelectric plants, and other sources of electrical energy) to meet the energy demand of remote facilities, such as communication stations, military installations, and rural villages.
5. **Net metering:** Excess electricity produced from the consumer's PV system can be returned to the local utility grid. This excess can be "sold" to the utility or credited to the consumer's account.
6. **PV connection to utility grid:** Using grid-connected PV power enables consumers to supply a portion of the power they need and use utility-generated power at night or on very cloudy days.
7. **Utility power production:** PV power plants consume no fuel and produce no air or water pollution while silently generating electricity. PV systems, however, produce power only during daylight hours, and their output can differ due to weather conditions. Installing PV systems near other utility distribution equipment can prevent overloading of the substation equipment.

Active solar heating

Active solar heating involves the use of specially designed mechanical systems to increase the heat gained from the sunlight. Active solar heating systems use solar collectors, which absorb the light energy from the sun, changing that energy into heat energy. The heat energy is then used to provide hot water, space heating, or space cooling. Figure H9 shows the different types of solar collectors.

The two types of active solar heating systems are *liquid-based (*where water or an antifreeze solution is heated in a "hydronic" collector) and *air-based* (where the air is heated in an "air collector"). Heated water is transmitted through the active solar heating system by means of pumps, which results in increasing the system's efficiency.



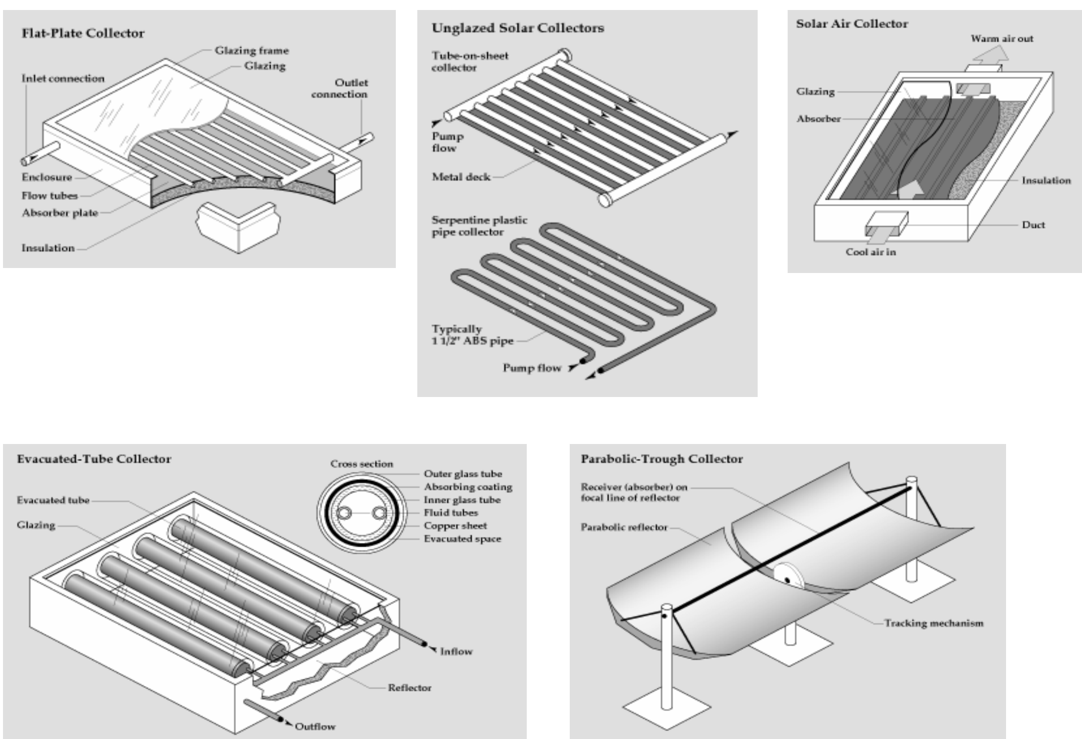


Figure H9. Solar collector types.

(Source: http://www.eere.energy.gov/solar/sh_basics.html)

Solar collectors, considered the “heart” of active solar heating systems, are categorized into four types:

- *flat-plate collectors*, which are insulated metal boxes with a glass or plastic cover (termed “glazing”) and a dark-colored absorber plate;
- *evacuated-tube collectors*, which consist of rows of parallel transparent glass tubes, each containing an absorber covered with a selective coating;
- *concentrating collectors*, which use curved mirrors to concentrate sunlight on an absorber (called a receiver) at up to 60 times the sun’s normal intensity; and
- *transpired air collectors*, which involve the sun heating a dark, performed metal and a fan pulling ambient air through the holes in the metal, which in turn heats the air.

Flat-plate collectors heat either liquid or air at temperatures less than 180 °F and are used for residential water heating and space heating applications. Evacuated-tube collectors are capable of operating at temperatures between 170 and 350 °F and are used in commercial and industrial applications, but are more expensive than flat-plate collectors. Concentrating collectors are used in commercial and industrial applications and are of the following types: *parabolic-trough collectors*, which use a tracking mechanism to keep the trough reflector pointed at the sun throughout the day, and *compound parabolic concentrating collectors*, which do not require an automatic sun-tracking system. Transpired air collectors do not require any glazing or insulation and have achieved efficiencies of more than 70 percent in a number of commercial applications.

Applications for using active solar heating are as follows:

1. **Residential and commercial water heating:** Solar water heating comprises two parts – a solar collector and a storage tank (e.g., a modified standard water heater). Solar water heaters, that utilize flat-plate collectors, are used to heat swimming pools and spas and can provide a payback as low as 2 years. Unglazed copper or copper-aluminum solar collectors are typically used for heating swimming pools. Glazed solar collectors are used only for indoor pools, hot tubs, and spas (in colder climates). Parabolic-trough concentrating systems can provide hot water and steam.
2. **Space heating:** Medium-temperature solar collectors are used in residential space heating applications. Transpired-air collectors are used in commercial and industrial ventilation air preheating applications. Solar

process heating systems, which are designed to meet the large demand for hot water, are applicable in the federal and state government markets that operate facilities that provide hot water for bathing, cooking, laundry, and space heating (e.g., schools, military bases, office buildings, prisons).

3. **Space cooling:** Active solar cooling systems can provide for year-round utilization of collected solar heat and can be sized for 30-60 percent of the facility's cooling requirements. Solar-driven absorption systems, using evacuated-tube or concentrating collectors, use the thermal energy from the solar collectors to separate a mixture of an absorbent and a refrigerant.
4. **Crop drying:** In addition to preheating ventilation air, transpired-air collectors are applicable in the international market, particularly in developing countries that have large quantities of coffee, grains, fruits, vegetables, and crops that need harvesting and drying.

Wind energy

Wind power (or wind energy) is defined as the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power, which can be used for specific functions (e.g., grinding grain, pumping water, etc.). Electricity from wind turbines is produced as follows: the wind turns the blades that, in turn, spin a shaft that connects to a generator. The generator produces the electricity. Figure H10 shows two different types of wind turbine configurations.

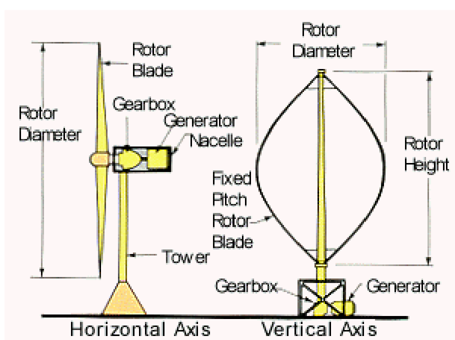


Figure H10. Wind turbine configurations.

Wind turbines are categorized into two types: *horizontal-axis wind turbines*, which typically have either two or three blades, and *vertical-axis wind turbines*, which have an egg-beater design. Single small wind turbines, sized below 50 kW, are used for homes, telecommunications dishes, or water pumping. Utility-scale wind turbines operate in size from 50 kW to a low number of megawatts. Wind farms result from the grouping of large wind turbines to provide vast power to the electrical grid.

Applications for using active solar heating are as follows:

1. **Water pumping:** Wind electric pumping systems allow greater siting flexibility, higher efficiency of wind energy conversion, increased water output, increased versatility in use of output power, and decreased maintenance and life-cycle costs.
2. **Stand-alone systems:** Wind power is the least-cost option for providing power to homes and businesses that are remote from an institutional grid.
3. **Systems for community centers, schools, and health clinics:** Larger wind energy systems can provide power to a centralized community center, school, or health clinic. A wind power system for a health center can enable the storage of vaccines and radio communication for emergency calls. A wind power system for a school can provide electricity for computers and educational television, video, and radio. Community centers, in addition to using wind power for lighting and cooling, can utilize the “waste energy” to charge batteries or make ice for sale to households.
4. **Industrial applications:** The industrial applications for wind energy include the following: telecommunications, radar, pipeline control, navigational aids, cathodic protection, weather stations, seismic monitoring, and air-traffic control.

Geothermal energy

Geothermal energy is defined (DOE 2006a) as energy in the form of heat from the Earth. This energy can be accessed by drilling water or steam wells in a process similar to that of drilling for oil. Most geothermal resources in the United States are in the western states, Alaska, and Hawaii. The three types of geothermal energy technologies are *geothermal power plants*, *geothermal* (or ground-source) *heat pumps* (see page 132), and *direct-use systems*, such as piped hot water.

Geothermal power plants are of the following three types: *dry-steam plants*, which directly use geothermal steam to turn turbines; *flash-steam plants*, which pull deep, high-pressure hot water into low-pressure tanks and use the resultant flash steam to drive turbines; and *binary-cycle plants*, which pass reasonably hot geothermal water by a secondary fluid (with a much lower boiling point temperature than water), which flashes to vapor, which in turn drives the turbines.

Direct-use systems (DOE 1998) involve the use of geothermal reservoirs of low to moderate temperature ranges of 68 to 302 °F (20 to 150 °C) and are applicable for heating homes, offices, and greenhouses. Aquaculture and food-processing plants also benefit from using this technology. According to the U.S. DOE's Geothermal Technologies Program, people at more than 120 locations (some of which include as many as 500 wells) use direct-use geothermal energy for space and district heating, including a few locations where waste heat is used for melting snow. Most direct-use systems utilize a heat exchanger to keep the geothermal water separate from the working fluid that carries heat to the application.

Hydroelectricity

Hydroelectricity, also termed hydropower or hydroelectric power, is defined as power created when flowing water is captured and turned into electricity. Turbines and generators convert the energy from the water into electricity, which is then fed into the electrical grid to be used by industry, and in residential and commercial communities (DOE 2005f). The two main types of hydroelectric turbines are as follows: impulse turbines, which typically use the velocity of the water to move the runner (or rotating part of the turbine) and discharge to atmospheric pressure; and reaction turbines, which develop power from the combined action of pressure and moving water, with the runner placed directly in the water stream flowing over the blades rather than striking each blade individually (DOE 2005i).

Hydroelectric plants are of the following three facility types:

- impoundment facilities, which use dams to store river water in a reservoir, with water released from the reservoir to flow through a turbine, activating a generator to produce electricity;
- diversion (or run-of-river) facilities, which direct a portion of a river through a canal or a penstock (defined as a closed conduit or pipe for conducting water to the powerhouse); and
- pumped storage facilities, which store energy during periods of low electrical demand by pumping water from a lower reservoir to a higher reservoir (DOE 2005h).

Hydroelectric power plant sizes (DOE 2005h) are categorized as follows:

- Micro hydropower plants, sized for capacities for up to 100 kW;

- Small hydropower plants, sized for capacities of 100 kW to 30 MW; and
- Large hydropower plants, sized for capacities greater than 30 MW.

Benefits

Biomass

According to DOE, biomass has been the leading source of renewable energy in the United States since 2000 (DOE 2006b). The benefits (DOE 2006l) of using biomass are the following:

- Biomass aids in moving the economy to a more sustainable basis because of energy options other than fossil fuels.
- Biomass is a domestic energy source, thereby reducing dependence on imported crude oil.
- Producing biomass and using agricultural residues will stimulate rural development efforts in farming, forestry, and associated service industries by creating new products, markets, and jobs.
- Biomass produces very low or no amount of CO_2 emissions.
- Biomass can also reduce the emissions of NO_x, sulfur dioxides, and other air pollutants associated with fossil fuel use.

Landfill gas

The benefits of using landfill-gas energy are the following:

- Direct reduction of greenhouse gas emissions;
- Indirect reduction of air pollution by avoiding the need to use non-renewable resources;
- Reduction of landfill odors;
- Creation of jobs associated with the design, construction, and operation of energy recovery systems;
- Generation of revenue from the sale of landfill gas;
- Cost savings over the life of landfill-gas energy projects; and
- Reduction of environmental regulatory compliance costs.

Army-owned landfill sites that were identified by the USEPA's Landfill Methane Outreach Program for potential landfill-gas energy projects are listed in Table H2.

Table H2. Army-owned landfills identified for potential landfill-gas energy projects.

Landfill Name	Landfill City	Landfill County	State	Waste In Place (tons)	Year Landfill Opened	Landfill Closure Year
Reserve Component Training Center	Fort Irwin (Mil Res)	San Bernardino	CA	7,577,621		2405
Fort Leonard Wood SLF		Pulaski	MO	181,696	1978	1994
Fort Campbell LF	Fort Camp-bell	Montgomery	TN	1,000,000	1987	1996

Photovoltaics

The benefits (DOE 2006t) of using the PV technology are as follows:

- PV systems are highly reliable and require little maintenance.
- PV systems cost little to build and operate.
- PV systems burn no fuel, have no moving parts, and are clean and silent, thereby producing no atmospheric emissions or greenhouse gases.
- PV systems are produced *domestically*, thereby reducing the nation's dependence on foreign oil.
- PV systems protect the nation against the threats of fuel price volatility and political instability.
- Building the PV industry creates domestic jobs and strengthens the economy.
- PV systems, because of their modularity, can be constructed in any size in responses to the energy needs at hand, or can be enlarged or moved as these needs change.
- Electricity generated by grid-connected PV arrays can be used directly to help supply a building's peak demand (often called "peak shaving").
- PV systems can produce power near the point of use before the grid becomes overloaded.
- PV systems help energy service providers (e.g., power plants) manage uncertainty and mitigate risk.

Active Solar Heating

The benefits (DOE 2006u) of using active solar heating systems are as follows:

- The fuel is free.
- The system would require expenditures only for O&M once the higher initial costs are recovered through reduced or avoided utility costs.

- Solar water heaters and other solar technology applications do not pollute the air.

Wind Energy

Wind is actually a form of solar energy caused by the heating of the atmosphere by the sun, the rotation of the earth, and the Earth's surface irregularities. Wind energy provides the following benefits (DOE 2005e):

Wind energy does not pollute the air, and is one of the lowest-priced renewable energy technologies available today with typical costs between $0.04 and $0.06/kWh, depending upon the wind resource and financing of the particular project. Wind turbines do not produce atmospheric emissions that cause acid rain or greenhouse gases. As a domestic source of energy produced in the United States, the Nation’s wind supply is abundant. Wind energy relies on the renewable power of the wind, which cannot be used up. Additionally, wind turbines can be built on farms or ranches, thus benefiting the economy in rural areas, where most of the best wind sites are found. Farmers and ranchers can continue to work the land because the wind turbines use only a fraction of the area. Wind power-plant owners make rent payments to the farmer or rancher for the use of the land.

Geothermal energy

Geothermal energy provides the following benefits (DOE 2006g, 2006h, 2006i, and 2006j):

- Clean air standards can be met.
- Solid waste generation is minimized and minerals can be recovered/recycled.
- Water quality and conservation standards can be met.
- Land use and environmental impact are both minimal.
- There is less dependence on imported energy.
- Enables the use of geothermal resources to keep the money spent on energy local.
- Development of geothermal power plants and direct-use applications creates a variety of jobs.

Hydroelectricity

Hydroelectricity provides the following benefits (DOE 2005g):

- Hydroelectricity is fueled by water and is a clean fuel source.
- Hydroelectricity does not pollute the air.
- Hydroelectricity is a domestic source of energy.
- Hydroelectricity relies on the water cycle, which is driven by the sun, and is thereby a renewable power source.
- Engineers at hydroelectric power plants can control the flow of water through the turbines to produce electricity on demand; therefore, hydroelectricity is available as needed.

Disadvantages

Biomass

The disadvantages (San Diego 2005) of using the biomass technology are as follows:

- Intentionally growing biomass for fuel, e.g., by fast rotation wood farms, could be counterproductive, since it competes with food production, which requires the same scarce resources of land, water, and nutrients.
- Growing biomass for use as energy fuel is inevitably more expensive than using wastes that others have generated. The costs of land, water, silviculture, and harvesting for an energy growth plantation are always additive to the costs of processing (chipping or grinding) and transportation.
- Due to its relatively low heat of combustion per unit volume, and the less dense resource as compared to fossil fuels, as well as the fact that biomass is solid, the cost of biomass as an energy source will always be high, if the cost for collection and transportation are included.
- Biomass availability is subject to seasonal variation.

Landfill gas

The disadvantages (Green Power 2006) of using landfill gas are as follows:

- When landfill gas is converted to energy in an internal combustion engine, dangerous compounds, such as nitrogen oxide, carbon monoxide, and dioxin are produced.

- The cost of electricity from landfill gas projects is higher relative to conventional fossil-fuel based electricity.

Photovoltaics

Among the disadvantages (UCF 2006) of using the PV technology are as follows:

- The initial cost of PV modules and equipment (compared to conventional energy sources) is high, although the economic value of PV systems is realized over many years.
- The surface area requirements for PV arrays may be a limiting factor.

Active solar heating

The disadvantages (F-A-S-E 2006) of using active solar heating or any solar technology are as follows:

- The initial cost of installing a solar energy system is high.
- The cost of solar energy is also high compared to nonrenewable utility-supplied electricity.
- Solar panels often require a large area for installation to achieve a good level of efficiency.
- The efficiency of the system also relies on the location of the sun, although this problem can be overcome with the installation of certain components.
- The production of solar energy is influenced by the presence of clouds or pollution in the air. Furthermore, no solar energy would be produced during nighttime unless there is a battery backup system and/or net metering in place.

Wind energy

Wind power must compete with conventional generation sources on a cost basis, and wind energy technology requires a higher initial investment than fossil-fueled generators. The major challenge to using wind as a source of power is that the wind is intermittent and does not always blow when electricity is needed. Wind energy cannot be stored (unless batteries are used); and not all winds can be harnessed to meet the timing of electricity demands. Good wind sites are often located in remote locations, far from cities where the electricity is needed. Wind resource development may compete with other uses for the land, and those alternative uses may be more highly valued than electricity generation. While wind power plants have considerably minimal impact on the environment compared to other conventional power plants, there is concern over noise produced by the rotor blades, visual impacts, and birds killed by flying into the rotors (DOE 2005e).

Hydroelectricity

The disadvantages (DOE 2005d) of using hydroelectricity are the following:

- Fish populations can be impacted if fish cannot migrate upstream past impoundment dams to spawning grounds or if they cannot migrate downstream to the ocean.
- Hydropower can impact water quality and flow.
- Hydropower plants can be impacted by drought.
- New hydropower facilities affect the local environment and may compete with other uses for the land.

Generic costs

Biomass

The cost of biomass fuels is dependent upon the following cost factors: climate, closeness to population centers, and the presence of industries that handle and dispose of wood. Typically the cost of biomass fuels must be equal to or less than the cost of coal per unit of heat for co-firing to be economically successful. In addition, the economics of co-firing with biomass is dependent upon location, power plant type, and the availability of low-cost biomass fuels (NREL 2006). A list of biomass energy system manufacturers in the United States is located at the following website:

> http://energy.sourceguides.com/businesses/byGeo/US/byP/biomass/biosystems/byB/mfg/byN/byName.shtml.

Landfill gas

The cost to generate electricity from landfill gas depends upon a variety of factors, including: (a) the presence or absence of a gas-recovery system; (b) the size of the landfill; and (c) the type of conversion technology used. Capital cost components would include collection system costs, administrative fees, grid interconnection costs, generating equipment costs, and contingency. Furthermore, there are O&M costs associated with both the collection system and the generating equipment. The cost of electricity generation from landfill gas can range from as low as $0.034/kWh to as high as $0.10/kWh (Chen and Greene 2003).

Photovoltaics

Cost factors for PV systems to determine a system's break-even turnkey cost include the following: (1) availability of rebates and net metering, (2) tax credits, and (3) utility electricity rates. Capital costs for PV systems vary depending on the chosen PV technology, installation specifics (e.g., roof type, contractor costs), the size of the system, and the supplier's retail mark-up. Other capital costs besides the PV module cost include: (1) the balance-of-system which includes the mounting equipment, the AC-to-DC power inverter, and the electrical wiring and connection equipment; and (2) site evaluation, permitting, and design and installation services. O&M costs for PV systems are less than $0.01/kWh (http://www.repartners.org/solar/pvcost.htm), and scheduled O&M involves washing the modules to remove dirt and dust. A list of PV manufacturers in the United States is located at the following website: http://www.solarplaza.com/content/pvportal_results.php?category=&keywords=Enter+keyword%3A&continent=6&country=223&ms=M&submit=Search.

Active solar heating

The electrical cost of active solar heating systems depends on the following factors: capital cost, O&M cost, and system performance. A typical 50-MW parabolic trough plant with a levelized cost of $0.11/kWh operates with a capital cost of $2,700/kW, an O&M cost of $0.024/kWh, and a fuel cost of $0.00/kWh (http://www.eere.energy.gov/troughnet/pdfs/kearney_wrec_2004.pdf).

A list of active solar heating manufacturers in the United States is located at the following websites:

For solar air heating:
http://energy.sourceguides.com/businesses/byGeo/US/byP/solar/sHeat/byB/mfg/mfg.shtml.

For solar water heating:
http://energy.sourceguides.com/businesses/byGeo/US/byP/solar/sWH/byB/mfg/byN/byName.shtml.

Wind energy

The cost of a wind system is in two parts: *initial installation costs*, which include the purchase price of the complete system (i.e., tower, wiring, utility interconnection or battery storage equipment, power conditioning unit, etc.), plus delivery and installation charges, professional fees and sales tax; and *operating expenses* (including maintenance and service, insurance and applicable taxes), which are incurred over the life of the wind system. The total installation cost is defined as a function of the wind system's rated electrical capacity. Annual operating expenses, as a rule of thumb, are 2 to 3 percent of the initial system cost (Iowa St. 2005).

A list of wind energy product manufacturers in the United States is located at the following website:

http://energy.sourceguides.com/businesses/byGeo/US/byP/wRP/byB/mfg/byN/byName.shtml.

Hydroelectricity

Typical capital costs for large hydroelectric plants are approximately $1,700 to $2,300 per kW, with O&M costs estimated at $0.07/kWh (NREL 2002).

Financing Requirements and Energy Incentives for Cost-Effective Implementation

Executive Order 13123 (Greening the Government Through Efficient Energy Management), Section 204, states the following: "Each agency shall strive to expand the use of renewable energy within its facilities and in its activities by implementing renewable energy projects and by purchasing electricity from renewable energy sources." Additionally, Title II, Section 203 of the EPAct05 states that the amount of renewable energy consumed by the Federal Government during any fiscal year shall be as follows:

1. Not less than 3 percent in fiscal years 2007 through 2009.
2. Not less than 5 percent in fiscal years 2010 through 2012.
3. Not less than 7.5 percent in fiscal year 2013 and each fiscal year thereafter.

Table H3 lists Federal energy incentives for implementation of renewable energy technologies based on information from the Database of State Incentives for Renewable Energy (DSIRE) (http://www.dsireusa.org).

Table H3. Federal energy incentives for renewable energy technologies.

Incentive	Eligible Renewable/Other Technologies	Incentive Website
Business Energy Tax Credit	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, geothermal electric, fuel cells, solar hybrid lighting, direct use geothermal, microturbines	http://www.dsireusa.org/documents/Incentives/US02F.htm
Energy Efficient Mortgage	Passive solar space heat, solar water heat, solar space heat, photovoltaics, daylighting	http://www.natresnet.org/resources/lender/default.htm
Modified Accelerated Cost-Recovery System (MACRS)	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, geothermal electric, fuel cells, solar hybrid lighting, direct use geothermal, microturbines	http://www.dsireusa.org/documents/Incentives/US06F.htm
Renewable Electricity Production Tax Credit	Landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, refined coal, Indian coal, small hydroelectric	http://www.dsireusa.org/documents/Incentives/US13F.pdf
Renewable Energy Production Incentive (REPI)	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, livestock methane, tidal energy, wave energy, ocean thermal, fuel cells (renewable fuels)	http://www.eere.energy.gov/wip/program/repi.html
Residential Energy Conservation Subsidy Exclusion (Corporate)	Solar water heat, solar space heat, photovoltaics	http://www.dsireusa.org/documents/Incentives/US31F.htm
Residential Energy Conservation Subsidy Exclusion (Personal)	Solar water heat, solar space heat, photovoltaics	http://www.dsireusa.org/documents/Incentives/US03F1.htm
Residential Energy Efficiency Tax Credit	Geothermal heat pumps	http://www.irs.gov/newsroom/article/0,,id=154657,00.html
Residential Solar and Fuel Cell Tax Credit	Solar water heat, photovoltaics, fuel cells	http://www.dsireusa.org/documents/Incentives/US37F.pdf
Tribal Energy Program Grant	Passive solar space heat, solar water heat, solar space heat, photovoltaics, wind, biomass, hydroelectric, geothermal electric, geothermal heat pumps	http://www.eere.energy.gov/tribalenergy/financial.html
USDA Renewable Energy Systems and Energy Efficiency Improvements Program	Solar water heat, solar space heat, photovoltaics, wind, biomass, geothermal electric, geothermal heat pumps, hydrogen, direct-use geothermal, anaerobic digestion, renewable fuels, fuel cells (renewable fuels)	http://www.dsireusa.org/documents/Incentives/US05Fa.pdf
Veterans Housing Guaranteed and Insured Loans	Passive solar space heat, solar water heat, solar space heat	http://www.federalgrantswire.com/veterans_housingguaranteed_and_insured_loans.html

Table H4 lists state-by-state energy incentives for implementation of renewable energy technologies based on information from DSIRE.

Table H4. State energy incentives for renewable energy technologies.

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
Alabama	Renewable Fuels Program	Landfill gas, biomass, municipal solid waste	http://www.adeca.state.al.us/txtlstvw.aspx?LstID=7d865154-617a-495b-afb8-5cf4271b56ed
	Wood-Burning Heating System Deduction	Biomass	http://www.dsireusa.org/documents/Incentives/AL01F.htm
Alaska	Golden Valley Electric - Sustainable Natural Alternative Power (SNAP) Program	Solar thermal electric, photovoltaics, wind, biomass	http://www.gvea.com/alternative-energy/snap/
	Power Project Loan Fund	Solar water heat, solar space heat, solar thermal electric, photovoltaics, wind, renewable transportation fuels, municipal solid waste	http://akenergyauthority.org/programsloan.html
Arizona	Environmental Portfolio Standard	Solar water heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, solar air-conditioning	http://www.cc.state.az.us/utility/electric/environmental.htm
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.cc.state.az.us/utility/electric/UIS_Documents.htm
	Qualifying Wood Stove Deduction	Biomass, (wood stoves)	http://www.dsireusa.org/documents/Incentives/AZ10F2.htm
	Renewable Energy and Energy Efficiency in New State Buildings	Solar water heat, solar space heat, photovoltaics, wind, biomass	http://www.dsireusa.org/documents/Incentives/AZ16R.pdf
Arkansas	Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, fuel cells, microturbines using renewable fuels	http://www.dsireusa.org/documents/Incentives/AR03R.htm
	Interconnection Standards	Photovoltaics, wind, biomass, hydroelectric, fuel cells, microturbines	http://www.dsireusa.org/documents/Incentives/AR03R.htm
California	Net Metering	Photovoltaics, landfill gas, wind, fuel cells, anaerobic digestion	http://www.dsireusa.org/documents/Incentives/CA02R1.pdf
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.energy.ca.gov/distgen/ interconnection/california_requirements.html
	Power Source Disclosure Program	Solar Thermal Electric, Photovoltaics, Wind, Biomass, Geothermal Electric, Municipal Solid Waste, Small Hydroelectric	http://www.dsireusa.org/documents/Incentives/CA01R1.htm
	Renewables Resource Trust Fund	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, municipal solid waste, anaero-	http://www.energy.ca.gov/renewables/02-REN-1038/index.html

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
		bic digestion, small hydroelectric (Note: small hydro is 30 MW or less), tidal energy, wave energy, ocean thermal, fuel cells (renewable fuels)	
	Renewables Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, anaerobic digestion, tidal energy, wave energy, ocean thermal, fuel cells (renewable fuels)	http://www.energy.ca.gov/portfolio/index.html
	San Diego – Green Power Purchasing	Solar water heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, fuel cells, municipal solid waste, digester gas, small hydroelectric, tidal energy, wave energy, ocean thermal	http://clerkdoc.sannet.gov/RightSite/getcon-tent/local.pdf?DMW_OBJECTID=09001451800a80a9
	San Diego – Sustainable Building Policy	Passive solar space heat, solar water heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, fuel cells, municipal solid waste, digester gas, daylighting, small hydroelectric, tidal energy, wave energy, ocean thermal	http://www.usgbc.org/Chapters/LosAngeles/Docs/MGBCE_ArnoldTom.pdf
	Santa Monica - Green Building Grant Program	Passive solar space heat, solar water heat, solar space heat, photovoltaics, wind, biomass, hydroelectric, bio-gas	http://greenbuildings.santa-monica.org/mainpages/whatsnew.htm
	Santa Monica - Green Power Purchasing	Biomass, geothermal electric	http://santa-monica.org/epd/residents/Energy/green_energy.htm
	Supplemental Energy Payments	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, geothermal heat pumps, municipal solid waste, anaerobic digestion, small hydroelectric, tidal energy, wave energy, ocean thermal, biodiesel, fuel cells (renewable fuels)	http://www.energy.ca.gov/portfolio/
Colorado	Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, anaerobic digestion, small hydroelectric, fuel cells (renewable fuels)	http://www.dora.state.co.us/puc/rulemaking/Amendment37.htm
	Cooperative Utilities – Interconnection Standards	Photovoltaics, landfill gas, wind, biomass, hydroelectric, municipal solid waste	http://www.gcea.coop/consumerserv/netmetering.cfm
	Delta-Montrose Electric Association - Net Metering	Photovoltaics, wind, biomass, hydroelectric, solar	http://www.dmea.com/
	Fuel Mix Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric	http://www.dsireusa.org/documents/Incentives/CO17R.htm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Holy Cross Energy - Net Metering	Photovoltaics, wind, biomass, hydroelectric, geothermal electric	http://www.holycross.com/
	Holy Cross Energy - WE CARE Rebates	Photovoltaics, wind, biomass, hydroelectric, geothermal electric	http://www.holycross.com/goto/Renewable_Generation
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, CHP/cogeneration, anaerobic digestion, fuel cells (renewable fuels), microturbines, other distributed generation technologies	http://www.dsireusa.org/documents/Incentives/CO28Rc.pdf
	Renewable Energy Standard	Photovoltaics, landfill gas, wind, biomass, geothermal electric, anaerobic digestion, small hydroelectric, fuel cells (renewable fuels)	http://www.dora.state.co.us/puc/rulemaking/Amendment37.htm
Connecticut	Green Power Purchase Plan	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, fuel cells, low-emission advanced renewable-energy conversion technologies, small hydroelectric, tidal energy, wave energy, ocean thermal	http://www.dsireusa.org/documents/Incentives/CT07R.htm
	Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, fuel cells, municipal solid waste, small hydroelectric, tidal energy, wave energy, ocean thermal	http://www.dsireusa.org/documents/Incentives/CT01R.htm
	Connecticut Clean Energy Fund	Photovoltaics, biomass, hydroelectric, fuel cells, hydrogen, tidal energy, wave energy, ocean thermal	http://www.ctcleanenergy.com/
	Energy Conservation Loan	Passive solar space heat, solar water heat, solar space heat, photovoltaics, wind, biomass, geothermal heat pumps	http://www.chif.org/owner_borrowers/index.shtml#energy
	Fuel Mix & Emissions Disclosure	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, tidal energy, wave energy, ocean thermal	http://www.dpuc.state.ct.us/EL_Aggre.nsf
	Interconnection Standards	Photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.dsireusa.org/documents/Incentives/CT06R.doc
	New Energy Technology Program	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, geothermal heat pumps, municipal solid waste, CHP/cogeneration, solar pool heating, daylighting, anaero-	http://www.opm.state.ct.us/pdpd2/grants/net.htm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
		bic digestion, tidal energy, wave energy, ocean thermal	
	On-Site Renewable DG Program	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells	http://www.ctcleanenergy.com/investment/onsite_renewable_dg_program.html
	Operational Demonstration Program	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, fuel cells, CHP/cogeneration, small hydroelectric, tidal energy, wave energy, ocean thermal, other distributed generation technologies	http://www.ctcleanenergy.com/investment/operational_demo_program.html
	Project 100 Initiative	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, fuel cells, small hydroelectric, tidal energy, wave energy, ocean thermal	http://www.ctcleanenergy.com/investment/Project100.html
	Renewable Energy Projects in Pre-Development Program	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, fuel cells, anaerobic digestion, tidal energy, wave energy, ocean thermal	http://www.ctcleanenergy.com/investment/Pre-DevelopmentProgram.html
	Renewables Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, low-E renewables, tidal energy, wave energy, ocean thermal	http://www.dsireusa.org/documents/Incentives/CT04Rb.htm
Delaware	Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric	http://www2.state.de.us/publicadvocate/dpa/html/self_gen.asp
	Fuel Mix Disclosure	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric	http://www.dsireusa.org/documents/Incentives/DE03R.htm
	Interconnection Standards	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, other distributed generation technologies	http://www2.state.de.us/publicadvocate/dpa/html/self_gen.asp
	Renewable Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, tidal energy, wave energy, ocean thermal, fuel cells (renewable fuels)	http://www.dsireusa.org/documents/Incentives/DE06R.doc
	Research and Development Grants	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable fuel vehicles, geothermal electric, fuel cells, municipal solid waste, hydrogen, solar, daylighting, anaerobic digestion, renewable fuels, ethanol, methanol, biodiesel	http://www.dsireusa.org/documents/Incentives/DE04Fa1.htm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
District of Columbia	Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, fuel cells, CHP/cogeneration, anaerobic digestion, tidal energy, microturbines	http://dceo.dc.gov/dceo/cwp/view,a,3,q,601821.asp
	Fuel Mix Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, tidal energy	http://www.dcpsc.org/customerchoice/whatis/electric/elec_restruc.shtm#Link19
	Interconnection Standards	Photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, microturbines	http://dceo.dc.gov/dceo/cwp/view,a,3,q,601821.asp
	Reliable Energy Trust Fund	Solar water heat, photovoltaics, wind, biomass, hydroelectric, anaerobic digestion, tidal energy	http://www.dsireusa.org/documents/Incentives/DC05R.htm
	Renewable Energy Demonstration Project (REDP)	Photovoltaics, wind, biomass, geothermal heat pumps, small hydroelectric, fuel cells (renewable fuels)	http://dceo.dc.gov/dceo/cwp/view.asp?a=3&q=603165&dceoNav=%7C32970%7C
	Renewables Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, co-firing, tidal energy, wave energy, ocean thermal	http://www.dccouncil.washington.dc.us/images/00001/20050105125710.pdf
Florida	Florida Renewable Energy Production Tax Credit	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, CHP/cogeneration, hydrogen, tidal energy, wave energy, ocean thermal	http://www.dsireusa.org/documents/Incentives/FL36F.pdf
	JEA – Clean Power Program	Photovoltaics, landfill gas, wind, biomass, municipal solid waste	http://www.jea.com/community/cleanpower.asp
	Renewable Energy Technologies Grants Program	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, hydroelectric, geothermal electric, geothermal heat pumps, CHP/cogeneration, hydrogen, solar pool heating, tidal energy, wave energy, ocean thermal	http://www.dsireusa.org/documents/Incentives/FL34F.pdf
Hawaii	High Technology Business Investment Tax Credit	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, geothermal electric, fuel cells, geothermal heat pumps, solar, wave energy, ocean thermal	http://www.state.hi.us/tax/announce/2003ann01.htm
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.dsireusa.org/documents/Incentives/HI01R.htm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Renewable Portfolio Standard	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, geothermal electric, geothermal heat pumps, municipal solid waste, CHP/cogeneration, hydrogen, seawater AC, solar AC, ice storage, anaerobic digestion, wave energy, ocean thermal, ethanol, methanol, biodiesel, fuel cells (renewable fuels)	http://www.hawaii.gov/dbedt/info/energy/
Idaho	Avista Utilities - Interconnection Guidelines	Photovoltaics, wind, biomass, hydroelectric, fuel cells	http://www.avistautilities.com/assets/tariffs/id/id_062.pdf
	Avista Utilities - Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, fuel cells	http://www.avistautilities.com/assets/tariffs/id/ID_062.pdf
	BEF - Renewable Energy Grant	Solar water heat, solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, animal waste-to-energy	http://www.b-e-f.org/grants/index.shtm
	Idaho Power - Interconnection Guidelines	Photovoltaics, wind, biomass, hydroelectric, fuel cells, other distributed generation technologies	http://www.idahopower.com/aboutus/business/generationinterconnect/default.htm
	Idaho Power - Net Metering	Photovoltaics, wind, biomass, hydroelectric, fuel cells	http://www.dsireusa.org/documents/Incentives/ID01R2.htm
	Low Interest Energy Loan Programs	Solar water heat, solar space heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal heat pumps, CHP/cogeneration	http://www.idwr.idaho.gov/energy/loans/default.htm
	Renewable Energy Equipment Sales Tax Refund	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, CHP/cogeneration	http://www.dsireusa.org/documents/Incentives/ID08F.htm
	Renewable Energy Project Bond Program	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, CHP/cogeneration	http://www.dsireusa.org/documents/Incentives/ID06F2.htm
	Residential Alternative Energy Tax Deduction	Passive solar space heat, solar water heat, solar space heat, photovoltaics, wind, biomass, geothermal heat pumps	http://www.dsireusa.org/documents/Incentives/ID01F.htm
	Utah Power & Light - Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric	http://www.utahpower.net/File/File3880.pdf
Illinois	ComEd – Interconnection Guidelines	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.comedtransmission.com/ipp.services/
	Fuel Mix and Emissions Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric	http://www.icc.illinois.gov/en/ecEnvironment.aspx

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Illinois Clean Energy Community Foundation Grants	Passive solar space heat, solar water heat, solar space heat, solar thermal process heat, photovoltaics, wind, biomass, fuel cells, other distributed generation technologies	http://www.illinoiscleanenergy.org/grants.asp
	Renewable Energy Resources Trust Fund	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, hydroelectric, geothermal electric, fuel cells	http://www.dsireusa.org/documents/Incentives/IL01R.htm
	Renewable Portfolio Goal	Solar water heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, CHP/cogeneration, “other such alternative sources of environmentally preferable energy”	http://www.dsireusa.org/documents/Incentives/IL04R.pdf
	State of Illinois - Green Power Purchasing	Solar thermal electric, photovoltaics, wind, biomass, solar, small hydroelectric	http://www100.state.il.us/PressReleases/ShowPressRelease.cfm?SubjectID=3&RecNum=1751
Indiana	Alternative Power & Energy Grant Program	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, municipal solid waste, CHP/cogeneration, sewage treatment, coal-mine methane, anaerobic digestion, fuel cells (renewable fuels)	http://www.in.gov/energy/programs/current.html
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, CHP/cogeneration, anaerobic digestion, microturbines, other distributed generation technologies	http://www.dsireusa.org/documents/Incentives/IN04R.pdf
Iowa	Alternate Energy Revolving Loan Program	Solar water heat, solar space heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric	http://www.energy.iastate.edu/funding/aerlp-index.html
	Alternative Energy Law (AEL)	Photovoltaics, wind, biomass, hydroelectric, municipal solid waste	http://www.dsireusa.org/documents/Incentives/IA01R.htm
	Energy Replacement Generation Tax Exemption	Landfill gas, wind, biomass, hydroelectric	http://www.dsireusa.org/documents/Incentives/IA10F.htm
	Fuel Mix Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, solar, other distributed generation technologies	http://www.dsireusa.org/documents/Incentives/IA06R.pdf
	Grants for Energy Efficiency and Renewable Energy Research	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, municipal solid waste	http://www.dsireusa.org/documents/Incentives/IA07F.htm
	Net Metering	Photovoltaics, wind, biomass, hydroelectric, municipal solid waste	http://www.dsireusa.org/documents/Incentives/IA02R.pdf
	Iowa Building Energy	Passive solar space heat, solar water	http://www.iowadnr.com/energy/ebank/in

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Management Program (Iowa Energy Bank)	heat, solar space heat, solar thermal electric, photovoltaics, wind, biomass, hydroelectric, renewable transportation fuels, geothermal heat pumps	dex.html
	Mandatory Utility Green Power Option	Photovoltaics, wind, biomass, hydroelectric, municipal solid waste	http://www.dsireusa.org/documents/Incentives/IA03R.htm
	Methane Gas Conversion Property Tax Exemption	Landfill gas, biomass	http://www.iowadnr.com/energy/renewable/incentives/methane.html
	Renewable Energy Production Tax Credit (Personal)	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydrogen, anaerobic digestion	http://www.state.ia.us/government/com/util/TaxCredits.html
	Renewable Energy Production Tax Credits (Corporate)	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydrogen, anaerobic digestion	http://www.state.ia.us/government/com/util/TaxCredits.html
	Green Power Procurement	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, municipal solid waste, anaerobic digestion, small hydroelectric	http://www.dsireusa.org/documents/Incentives/IA08R.pdf
Kansas	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste	http://www.dsireusa.org/documents/Incentives/KS03R1.htm
	Renewable Energy Property Tax Exemption	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric	http://www.dsireusa.org/documents/Incentives/KS02F.htm
	State Energy Program Grants	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, renewable fuel vehicles, geothermal electric, fuel cells, geothermal heat pumps, CHP/cogeneration, energy education	http://www.kcc.state.ks.us/energy/forms.htm
Maine	Fuel Mix and Emissions Disclosure	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, tidal energy	http://www.state.me.us/mpuc/doing_business/rules/part_3/ch-306lf.htm
	Customer Net Energy Billing	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, tidal energy	http://www.dsireusa.org/documents/Incentives/ME02R.pdf
	Green Power Purchasing	Biomass, small hydroelectric	http://www.state.me.us/governor/baldacci/vision/environment.html
	Public Benefits Program	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, tidal energy	http://www.maine.gov/spo/energy/energycouncil/renewable.php

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Renewable Resources Matching Fund Program	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, tidal energy	http://www.mainetechnology.com/?cat_id=278
	Renewables Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, CHP/cogeneration, tidal energy	http://www.state.me.us/mpuc/doing_business/rules/part_3/ch-311.htm
Maryland	Clean Energy Production Tax Credit	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, co-firing, anaerobic digestion	http://www.dsireusa.org/documents/Incentives/MD16F.htm
	Fuel Mix and Emissions Disclosure	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, municipal solid waste, anaerobic digestion	http://www.dsireusa.org/documents/Incentives/MD04R.htm
	Interconnection Standards	Biomass	http://www.dsireusa.org/documents/Incentives/MD01F3.htm
	Net Metering	Photovoltaics, wind, biomass, anaerobic digestion	http://www.energy.state.md.us/energyinformation/renewable/netmetering.htm
	Montgomery County - Clean Energy Rewards Program	Photovoltaics, landfill gas, wind	http://www.dsireusa.org/documents/Incentives/MD15F.pdf
	Renewable Energy Portfolio Standard and Credit Trading	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, anaerobic digestion, tidal energy, wave energy, ocean thermal, fuel cells (renewable fuels)	http://www.psc.state.md.us/psc/electric/rps/home.htm
	State of Maryland - Clean Energy Procurement	Landfill gas, wind, biomass, municipal solid waste	http://www.dsireusa.org/documents/Incentives/MD07R1.pdf
	Wood Heating Fuel Exemption	Biomass	http://www.dsireusa.org/documents/Incentives/MD01F3.htm
Massachusetts	Alternative Energy and Energy Conservation Patent Exemption (Corporate)	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, hydroelectric, renewable transportation fuels, geothermal electric, fuel cells, geothermal heat pumps, municipal solid waste	http://www.mass.gov/doer/programs/renew/renew.htm
	Alternative Energy and Energy Conservation Patent Exemption (Personal)	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, hydroelectric, renewable transportation fuels, geothermal electric, fuel cells, geothermal heat pumps, municipal solid waste	http://www.mass.gov/doer/programs/renew/renew.htm
	Clean Energy Pre-Development Financing Initiative - Grants	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, anaerobic digestion	http://www.masstech.org/grants_and_awards/CE/predev_overview.htm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Clean Energy Pre-Development Financing Initiative - Loans	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, anaerobic digestion	http://www.masstech.org/grants_and_awards/CE/predev_overview.htm
	Fuel Source and Emissions Disclosure	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, ocean thermal	http://www.mass.gov/dte/restruct/competition/index.htm
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.mtpc.org/cleanenergy/howto/interconnection/interconintro.htm
	Large Onsite Renewables Initiative Grants	Photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, anaerobic digestion, renewable fuels, biodiesel	http://www.masstech.org/renewableenergy/large_renewables.htm
	Renewable Energy Credit (REC) Payment Options	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, anaerobic digestion, tidal energy, wave energy, ocean thermal, fuel cells (renewable fuels)	http://www.mtpc.org/renewableenergy/mgpp.htm
	Renewable Energy Trust Fund	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, storage/conversion techs connected to renewables, anaerobic digestion, tidal energy, wave energy, ocean thermal, renewable fuels, biodiesel	http://www.mtpc.org/RenewableEnergy/index.htm
	Renewable Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, tidal energy, wave energy, ocean thermal, fuel cells (renewable fuels)	http://www.mass.gov/doer/rps/index.htm
	Sustainable Energy Economic Development (SEED) Initiative	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, fuel cells, municipal solid waste, anaerobic digestion, tidal energy, wave energy, ocean thermal	http://www.masstech.org/SEED/
Michigan	Biomass Energy Program Grants	Biomass, renewable transportation fuels, municipal solid waste	http://www.michigan.gov/cis/0,1607,7-154-25676_25753---,00.html
	Community Energy Project Grants	Passive solar space heat, solar water heat, solar space heat, photovoltaics, biomass, renewable transportation fuels, renewable fuel vehicles	http://www.michigan.gov/cis/0,1607,7-154-25676---,00.html
	Energy Efficiency Grants	Solar water heat, photovoltaics, wind, fuel cells, solar, anaerobic digestion	http://www.michigan.gov/mpsc/0,1607,7-159-16370_27289---,00.html
	Fuel Mix and Emissions Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geother-	http://www.cis.state.mi.us/mpsc/electric/restruct/regional_disclosure/fuelandemissi

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
		mal electric, fuel cells, municipal solid waste	ons.htm
	Interconnection Standards	Photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.dsireusa.org/documents/Incentives/MI02R.pdf
	Net Meeting	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste	http://www.michigan.gov/mpsc/0,1607,7-159-16393_38274---,00.html
Minnesota	Agricultural Improvement Loan Program	Wind, biomass, anaerobic digestion	http://www.mda.state.mn.us/AgFinance/improvement.html
	Energy Investment Loan Program	Solar water heat, solar space heat, solar thermal process heat, wind, biomass, geothermal heat pumps, solar pool heating	http://www.revisor.leg.state.mn.us/arule/7606/
	Fuel Mix and Emissions Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric	http://www.pca.state.mn.us/programs/electricity.html
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.puc.state.mn.us/docs/orders/04-0131.pdf
	Mandatory Utility Green Power Option	Photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells (renewable fuels), microturbines	http://www.revisor.leg.state.mn.us/stats/216B/169.html
	Net Metering	Photovoltaics, wind, biomass, hydroelectric, municipal solid waste, CHP/cogeneration	http://www.dsireusa.org/documents/Incentives/MN01R.htm
	Non-Mandated Renewable Energy Objective	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, municipal solid waste, hydrogen	http://www.dsireusa.org/documents/Incentives/MN07R.htm
	Renewable Development Fund Grants	Photovoltaics, wind, biomass, hydroelectric, CHP/cogeneration, anaerobic digestion, renewable fuels, fuel cells (renewable fuels)	http://www.xcelenergy.com/XLWEB/CDA/0,2914,1-1-1_4359_3725-801-2_171_258-0,00.html
	State of Minnesota Renewable Energy Production Incentive	Wind, biomass, hydroelectric, anaerobic digestion	http://www.state.mn.us/portal/mn/jsp/content.do?id=-536881350&subchannel=-536881511&sc2=null&sc3=null&contentid=536885915&contenttype=EDITORIAL&programid=536885394&agency=Commerce
	Value-Added Stock Loan Participation Program	Wind, biomass, anaerobic digestion	http://www.mda.state.mn.us/AgFinance/stockloan.html
	Xcel Energy Renewable	Photovoltaics, wind, biomass, hydroelec-	http://www.xcelenergy.com/XLWEB/CDA/

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Development Fund	tric, CHP/cogeneration, anaerobic digestion, renewable fuels, fuel cells (renewable fuels)	0,3080,1-1-1_11824_11838-801-5_538_985-0,00.html
	Xcel Energy Wind and Biomass Generation Mandate	Wind, biomass	http://www.dsireusa.org/documents/Incentives/MN03R.htm
Mississippi	Energy Investment Loan Program	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, biomass, hydroelectric, renewable transportation fuels, geothermal electric, municipal solid waste, CHP/cogeneration	http://www.mississippi.org/content.aspx?url=/page/2913&
Missouri	Columbia - Renewables Portfolio Standard	Photovoltaics, wind, biomass	http://www.dsireusa.org/documents/Incentives/MO04R.htm
	Energy Loan Program	Passive solar space heat, solar water heat, solar space heat, photovoltaics, wind, biomass	http://www.dnr.mo.gov/energy/financial/loan.htm
	Interconnection Standards	Photovoltaics, wind, biomass, fuel cells	http://www.sos.mo.gov/adrules/csr/current/4csr/4c240-20.pdf
	Wood Energy Production Credit	Biomass	http://www.sos.mo.gov/adrules/csr/current/10csr/10c140-4.pdf
Montana	Alternative Energy Investment Corporate Tax Credit	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, small hydroelectric, fuel cells (renewable fuels)	http://www.deq.state.mt.us/energy/Renewable/TaxIncentRenew.asp#15-32-401
	Alternative Energy Revolving Loan Program	Solar water heat, photovoltaics, landfill gas, wind, biomass, geothermal electric, geothermal heat pumps, small hydroelectric, fuel cells (renewable fuels)	http://www.deq.state.mt.us/energy/Renewable/altenergyloan.asp
	BEF - Renewable Energy Grant	Solar water heat, solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, animal waste-to-energy	http://www.b-e-f.org/grants/index.shtm
	Corporate Property Tax Reduction for New/Expanded Generating Facilities	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, small hydroelectric, fuel cells (renewable fuels)	http://www.deq.state.mt.us/energy/Renewable/TaxIncentRenew.asp#15-24-1401
	Fuel Mix and Emissions Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, small hydroelectric	http://www.dsireusa.org/documents/Incentives/MT02R.pdf
	Generation Facility Corporate Tax Exemption	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, small hydroelectric, fuel cells (renewable fuels)	http://www.deq.state.mt.us/energy/Renewable/TaxIncentRenew.asp#15-6-225
	Mandatory Green Power Program	Solar thermal electric, photovoltaics, wind, biomass, geothermal electric	http://www.montanagreenpower.com/greenpower/index.html
	NorthWestern Energy - USB	Photovoltaics, landfill gas, wind, bio-	http://www.northwesternenergy.com/show

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Renewable Energy Fund	mass, hydroelectric, geothermal electric	item.aspx?M=17&I=108
	Renewable Energy Systems Exemption	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, geothermal electric, geothermal heat pumps, municipal solid waste, solar pool heating, anaerobic digestion, small hydroelectric, fuel cells (renewable fuels)	http://deq.mt.gov/Energy/renewable/taxincentrenew.asp#15-6-201(4)
	Renewables Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, fuel cells (renewable fuels)	http://www.dsireusa.org/documents/Incentives/MT08R.htm
	Residential Alternative Energy System Tax Credit	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, geothermal electric, geothermal heat pumps, municipal solid waste, low-emission wood stoves, small hydroelectric, fuel cells (renewable fuels)	http://www.deq.state.mt.us/energy/Renewable/TaxIncentRenew.asp#15-32-201
Nebraska	Dollar and Energy Savings Loans	Solar water heat, solar space heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, renewable fuel vehicles, geothermal electric, municipal solid waste	http://www.neo.state.ne.us/loan/index.html
Nevada	Energy Portfolio Standard	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, waste tires (using microwave reduction), solar pool heating, anaerobic digestion, biodiesel	http://www.puc.state.nv.us/Renewable/REPSNevada_files/frame.htm
	Fuel Mix and Emissions Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, other distributed generation technologies	http://www.dsireusa.org/documents/Incentives/NV02R.htm
	Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric	http://www.nevadapower.com/conservation/alternative_energy/metering/index.cfm
	Portfolio Energy Credits	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, solar pool heating, anaerobic digestion	http://www.puc.state.nv.us/renewable_energy.htm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Property Tax Abatement for Green Buildings	Passive solar space heat, solar water heat, photovoltaics, landfill gas, wind, biomass, geothermal electric, daylighting, anaerobic digestion, small hydroelectric	http://www.dsireusa.org/documents/Incentives/NV10F.htm
	Renewable Energy Producers Property Tax Abatement	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, municipal solid waste, anaerobic digestion	http://energy.state.nv.us/renewable/incentives.htm
	Renewable Energy Systems Property Tax Exemption	Passive solar space heat, solar water heat, solar space heat, photovoltaics, wind, hydroelectric, geothermal electric, geothermal heat pumps, municipal solid waste	http://energy.state.nv.us/renewable/incentives.htm
New Jersey	Clean Energy Financing for Local Schools and Governments	Photovoltaics, wind, biomass, fuel cells (renewable fuels)	http://www.njcep.com/html/redo_program.html
	Environmental Information Disclosure	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, anaerobic digestion, tidal energy, wave energy	http://www.state.nj.us/bpu/home/energy.shtml
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, tidal energy, wave energy, fuel cells (renewable fuels)	http://www.dsireusa.org/documents/Incentives/NJ11R.htm
	Green Power Purchasing	Wind, biomass, hydroelectric, solar	http://www.state.nj.us/dep/dsr/bscit/CleanEnergyMain.htm
	Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, tidal energy, wave energy, fuel cells (renewable fuels)	http://www.state.nj.us/bpu/wwwroot/secretary/NetMeteringInterconnection-Rules.pdf
	New Jersey Clean Energy Rebate Program	Photovoltaics, landfill gas, wind, biomass, anaerobic digestion, fuel cells (renewable fuels)	http://www.njcep.com/html/2_incent.html
	Renewable Energy Business Venture Assistance Program (REBVAP)	Photovoltaics, landfill gas, wind, biomass, hydrogen, "balance of systems" technologies, tidal energy, wave energy, fuel cells (renewable fuels)	http://www.njcleanenergy.com/html/Combined/cleanenergy_financing.html
	Renewable Energy Economic Development Program (REED)	Photovoltaics, landfill gas, wind, biomass, hydrogen, tidal energy, wave energy, fuel cells (renewable fuels)	http://www.njcep.com/special/REED_2004_solicitation.pdf
	Renewables Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, resource-recovery facilities approved by the Department of Environmental Protection, anaerobic digestion, tidal energy, wave	http://www.dsireusa.org/documents/Incentives/NJ05Rb.htm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
		energy, fuel cells (renewable fuels)	
	Societal Benefits Charge	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, tidal energy, wave energy, fuel cells (renewable fuels)	http://www.bpu.state.nj.us/cleanEnergy/cleanEnergyProg.shtml
New Mexico	Biomass Equipment & Materials Deduction	Landfill gas, biomass, municipal solid waste, CHP/cogeneration, hydrogen, anaerobic digestion, ethanol, methanol, biodiesel, microturbines	http://www.dsireusa.org/documents/Incentives/NM06F.pdf
	Energy Efficiency & Renewable Energy Bond Program	Passive solar space heat, solar water heat, solar space heat, photovoltaics, wind, biomass, fuel cells, CHP/cogeneration, daylighting	http://www.dsireusa.org/documents/Incentives/NM07F.pdf
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.nmsea.org/Grid_Interconnection/Interconnection.htm
	Line Extension	Photovoltaics, wind, biomass, geothermal electric	http://www.dsireusa.org/documents/Incentives/NM03R.htm
	Mandatory Utility Green Power Option	Photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells	http://www.dsireusa.org/documents/Incentives/NM08R.htm
	Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines	http://www.dsireusa.org/documents/Incentives/NM01R.htm
	Renewable Energy Production Tax Credit	Solar thermal electric, photovoltaics, wind, biomass	http://www.dsireusa.org/documents/Incentives/NM02F.htm
	Renewables Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, fuel cells (renewable fuels)	http://www.nmprc.state.nm.us/utility/utilitydivhome.htm
New York	Energy $mart Loan Fund	Solar water heat, solar space heat, photovoltaics, landfill gas, wind, biomass, geothermal heat pumps	http://www.nyserda.org/loanfund/
	New York - Net Metering	Photovoltaics, wind, biomass	http://www.dps.state.ny.us/distgen.htm
	Renewable Portfolio Standard	Photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, CHP/cogeneration, biogas, liquid biofuel, anaerobic digestion, tidal energy, wave energy, ocean thermal	http://www.dps.state.ny.us/03e0188.htm
	Renewable Power Procurement Policy	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, fuel cells, other methane waste,	http://www.nyserda.org/programs/exorder111.asp

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
		tidal energy	
	Renewables R&D Grant Program	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, CHP/cogeneration	http://www.powernaturally.com/Funding/funding.asp?i=2
	Solar, Wind & Biomass Energy Systems Exemption	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, daylighting, anaerobic digestion	http://www.orps.state.ny.us/assessor/manu-als/vol4/part1/section4.01/sec487.htm
	Suffolk County - Green Power Purchasing Policy	Photovoltaics, wind, biomass, hydroelectric	http://www.lipower.org/residential/green.html
	System Benefits Charge	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, renewable transportation fuels, geothermal electric, fuel cells, CHP/cogeneration	http://www.dps.state.ny.us/sbc.htm
	New York - Net Metering	Photovoltaics, wind, biomass	http://www.dps.state.ny.us/distgen.htm
	Renewable Portfolio Standard	Photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, CHP/cogeneration, biogas, liquid biofuel, anaerobic digestion, tidal energy, wave energy, ocean thermal	http://www.dps.state.ny.us/03e0188.htm
	Renewable Power Procurement Policy	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, fuel cells, other methane waste, tidal energy	http://www.nyserda.org/programs/exorder111.asp
	Renewables R&D Grant Program	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, CHP/cogeneration	http://www.powernaturally.com/Funding/funding.asp?i=2
	Solar, Wind & Biomass Energy Systems Exemption	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, daylighting, anaerobic digestion	http://www.orps.state.ny.us/assessor/manu-als/vol4/part1/section4.01/sec487.htm
	Suffolk County - Green Power Purchasing Policy	Photovoltaics, wind, biomass, hydroelectric	http://www.lipower.org/residential/green.html
North Carolina	Energy Improvement Loan Program (EILP)	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, hydroelectric	http://www.energync.net/funding/docs/eilp.pdf
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, fuel cells, municipal solid waste, CHP/cogeneration, anaerobic digestion, small hydroelectric, microturbines, other distributed generation technologies	http://www.dsireusa.org/documents/Incentives/NC04R.pdf
	NC Green Power Production Incentive	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, anaerobic digestion	http://www.ncgreenpower.org/

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Net Metering	Photovoltaics, landfill gas, wind, biomass, anaerobic digestion	http://www.dsireusa.org/documents/Incentives/NC05R.pdf
	Renewable Energy Tax Credit - Corporate	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, spent pulping liquor, solar pool heating, daylighting, anaerobic digestion, ethanol, methanol, biodiesel	http://www.ncsc.ncsu.edu/information_resources/renewable_energy_tax_guidelines.cfm
	Renewable Energy Tax Credit - Personal	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, hydroelectric, renewable transportation fuels, spent pulping liquor, solar pool heating, daylighting, ethanol, methanol, biodiesel	http://www.ncsc.ncsu.edu/information_resources/renewable_energy_tax_guidelines.cfm
North Dakota	Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, CHP/cogeneration	http://www.dsireusa.org/documents/Incentives/ND01R.pdf
Ohio	Energy Conversion Facilities Corporate Tax Exemption	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, renewable transportation fuels, municipal solid waste, CHP/cogeneration	http://www.odod.state.oh.us/cdd/oee/c_i_cfe.htm
	Energy Conversion Facilities Property Tax Exemption	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, municipal solid waste, CHP/cogeneration	http://www.odod.state.oh.us/cdd/oee/c_i_cfe.htm
	Energy Conversion Facilities Sales Tax Exemption	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, renewable transportation fuels, municipal solid waste	http://www.odod.state.oh.us/cdd/oee/c_i_cfe.htm
	Energy Loan Fund (ELF)	Solar water heat, solar space heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines	http://www.odod.state.oh.us/cdd/oee/energy_loan_fund.htm
	Energy Loan Fund Grants - Distributed Energy and Renewable Energy	Solar water heat, solar space heat, photovoltaics, landfill gas, wind, biomass, CHP/cogeneration, anaerobic digestion, microturbines, other distributed generation technologies	http://www.odod.state.oh.us/cdd/oee/elfgrant.htm
	Environmental Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, solar,	http://www.puco.ohio.gov/PUCO/Consumer/information.cfm?doc_id=1191

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
		other distributed generation technologies	
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.puco.ohio.gov/PUCO/Consumer/information.cfm?doc_id=115
	Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, microturbines	http://www.puco.ohio.gov/PUCO/Consumer/information.cfm?doc_id=346
	Renewable Energy Loans	Solar water heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells	http://www.odod.state.oh.us/cdd/oee/elf_Renewable.htm
Oklahoma	Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, CHP/cogeneration	http://www.dsireusa.org/documents/Incentives/OK01R1.htm
Oregon	BEF – Renewable Energy Grant	Solar water heat, solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, animal waste-to-energy	http://www.b-e-f.org/grants/renew_criteria.shtm
	Business Energy Tax Credit	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, geothermal electric, geothermal heat pumps, CHP/cogeneration, hydrogen, industrial waste, refueling stations, ethanol, methanol, biodiesel, fuel cells (renewable fuels)	http://egov.oregon.gov/ENERGY/CONS/BUS/BETC.shtml
	Energy Trust - Open Solicitation Program	Photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, fuel cells (renewable fuels)	http://www.energytrust.org/RR/os/index.html
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, anaerobic digestion	http://www.dsireusa.org/documents/Incentives/OR14R.htm
	Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, anaerobic digestion	http://www.dsireusa.org/documents/Incentives/OR03R.htm
	Portland - Green Building Policy and LEED Certification	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, geothermal heat pumps, anaerobic digestion	http://www.green-rated.org/default.asp

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Portland - Green Power Purchasing & Generation	Photovoltaics, wind, biomass, geothermal electric, anaerobic digestion	http://www.portlandonline.com/osd/index.cfm?c=ecdjj&a=bbbhde
	Public Benefits Funds	Solar water heat, solar space heat, solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, direct-use geothermal energy, fuel cells (renewable fuels)	http://www.energytrust.org/RR/index.html
	Renewable Energy Systems Exemption	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, geothermal heat pumps, methane gas, solar pool heating	http://egov.oregon.gov/ENERGY/RENEW/Solar/Support.shtml
	Small-Scale Energy Loan Program	Passive solar space heat, solar water heat, solar space heat, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, geothermal electric, municipal solid waste, CHP/cogeneration, small hydroelectric, renewable fuels	http://egov.oregon.gov/ENERGY/LOANS/index.shtml
Pennsylvania	Alternative Energy Portfolio Standard	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, waste coal, coal mine methane, coal gasification, anaerobic digestion, other distributed generation technologies	http://www.puc.state.pa.us/electric/electric_alt_energy.aspx
	Commonwealth of Pennsylvania - Green Power Purchasing	Photovoltaics, landfill gas, wind, biomass, hydroelectric	http://www.dep.state.pa.us/newsletter/default.asp?NewsletterArticleID=9466
	Fuel Mix Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, CHP/cogeneration	http://www.puc.state.pa.us/utilitychoice/consumer_protections.aspx?ut=ec
	Metropolitan Edison Company Sustainable Energy Fund (SEF) Grants (FirstEnergy Territory)	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, CHP/cogeneration	http://www.bccf.org/pages/gr.energy.html
	Metropolitan Edison Company SEF Loans (FirstEnergy Territory)	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, CHP/cogeneration	http://www.bccf.org/pages/gr.energy.html
	Penelec SEF of the Community Foundation for	Passive solar space heat, solar water heat, solar space heat, solar thermal	http://www.cfalleghenies.org/page17909.cfm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	the Alleghenies Grant Program (FirstEnergy Territory)	electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, CHP/cogeneration	
	Penelec SEF of the Community Foundation for the Alleghenies Loan Program (FirstEnergy Territory)	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, CHP/cogeneration	http://www.cfalleghenies.org/page17909.cfm
	Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, municipal solid waste, CHP/cogeneration, waste coal, coal-mine methane; demand-side management technologies, anaerobic digestion, other distributed generation technologies	http://www.dsireusa.org/documents/Incentives/PA03Rb.htm
	Pennsylvania Energy Development Authority (PEDA) - Grants	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, fuel cells, geothermal heat pumps, coal-mine methane; waste coal, anaerobic digestion, small hydroelectric, other distributed generation technologies	http://www.depweb.state.pa.us/enintech/cwp/view.asp?a=1415&q=504241
	Pennsylvania Energy Development Authority (PEDA) - Loans and Loan Guarantees	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, geothermal electric, fuel cells, coal-mine methane; waste coal, anaerobic digestion, small hydroelectric	http://www.depweb.state.pa.us/enintech/cwp/view.asp?a=1415&q=504241
	Pennsylvania Energy Harvest Grant Program	Solar water heat, solar space heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, renewable transportation fuels, fuel cells, CHP/cogeneration, anaerobic digestion, small hydroelectric, other distributed generation technologies	http://www.depweb.state.pa.us/energy/cwp/view.asp?a=1374&q=483024
	Public Benefits Programs	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, geothermal heat pumps, municipal solid waste	http://www.puc.state.pa.us/utilitychoice/electricity/green_clean.aspx
	SEF of Central Eastern Pennsylvania Loan Program (PP&L Territory)	Solar water heat, solar space heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, CHP/cogeneration, other distributed generation technologies	http://www.thesef.org/
	Sustainable Development Fund Commercial Financing Program (PECO Territory)	Passive solar space heat, solar water heat, solar space heat, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells,	http://www.trfund.com/sdf/financing.html

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
		geothermal heat pumps	
	Sustainable Development Fund Grant Program (PECO Territory)	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, geothermal heat pumps, CHP/cogeneration	http://www.trfund.com/sdf/grants.html
	West Penn Power SEF Commercial Loan Program	Solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, CHP/cogeneration, other distributed generation technologies	http://www.wppsef.org/investments.html
Rhode Island	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://www.ripuc.state.ri.us/
	Renewable Energy Fund	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, solar thermal process heat, photovoltaics, wind, biomass, hydroelectric, renewable transportation fuels, geothermal electric, cofiring, tidal energy, wave energy, ocean thermal, fuel cells (renewable fuels)	http://www.riseo.ri.gov/
	Renewable Energy Standard	Photovoltaics, landfill gas, wind, biomass, geothermal electric, small hydroelectric, tidal energy, wave energy, ocean thermal, biodiesel, fuel cells (renewable fuels)	http://www.ripuc.org/eventsactions/docket/3659page.html
	Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration	http://www.dsireusa.org/documents/Incentives/RI01R.pdf
	Small Customer Incentive Program for Green Power Marketers	Photovoltaics, landfill gas, wind, biomass, geothermal electric, fuel cells, anaerobic digestion, small hydroelectric	http://www.riseo.state.ri.us/riref/programs/rfp.html
South Carolina	Conway - Green Power Purchasing	Landfill gas	http://www.santeecooper.com/greenpower/newsroom/releases/news_2002_0422.html
	Landfill Methane Tax Credit	Landfill gas	http://www.dsireusa.org/documents/Incentives/SC08F2.htm
	Myrtle Beach - Green Power Purchasing	Landfill gas	http://www.santeecooper.com/greenpower/index.html
	North Myrtle Beach - Green Power Purchasing	Landfill gas	http://www.santeecooper.com/greenpower/index.html
South Dakota	Renewable Energy Systems	Passive solar space heat, solar water	http://www.dsireusa.org/documents/Incen

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Exemption	heat, solar space heat, photovoltaics, landfill gas, wind, biomass, geothermal electric, ethanol	tives/SD01F.htm
Tennessee	Small Business Energy Loan Program	Solar water heat, solar space heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, renewable transportation fuels, geothermal electric, municipal solid waste	http://www.state.tn.us/ecd/energy_sbel.htm
Texas	Alternative Energy in New State Construction	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, photovoltaics, wind, biomass	http://www.dsireusa.org/documents/Incentives/TX06R.htm
	Austin - Renewables Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, tidal energy, wave energy	http://www.austinenergy.com/Energy%20Efficiency/Programs/Green%20Choice/index.htm
	Austin Energy - Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, anaerobic digestion	http://www.austinenergy.com/About%20Us/Rates/distributedGenerationFromRenewableSources.htm
	Fuel Mix and Emission Disclosure	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, tidal energy, wave energy, ocean thermal	http://www.puc.state.tx.us/rules/subrules/electric/25.476/25.476ei.cfm
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, CHP/cogeneration, reciprocating engines, turbines, storage , tidal energy, wave energy, ocean thermal, microturbines, other distributed generation technologies	http://www.puc.state.tx.us/rules/subrules/electric/index.cfm
	Renewable Energy Systems Property Tax Exemption	Passive solar space heat, solar water heat, solar space heat, photovoltaics, wind, biomass, anaerobic digestion	http://www.dsireusa.org/documents/Incentives/TX03F.htm
	Renewable Generation Requirement	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, tidal energy, wave energy, ocean thermal	http://www.puc.state.tx.us/rules/subrules/electric/25.476/25.476ei.cfm
	San Antonio City Public Service - Distributed Generation Program	Photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, tidal energy, wave energy	http://www.citypublicservice.com/content_listInternet.asp?cont_id=5458&elmt_id=11
	Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, tidal energy, wave energy, ocean thermal	http://www.puc.state.tx.us/rules/subrules/electric/25.242/25.242ei.cfm
Utah	Renewable Energy Sales Tax Exemption	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion	http://www.dsireusa.org/documents/Incentives/UT09F.htm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Renewable Energy Systems Tax Credit - Corporate	Passive solar space heat, solar water heat, solar space heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric	http://geology.utah.gov/sep/incentives/rincentives.htm#retaxcred
Vermont	Fuel Source and Environmental Impact Disclosure	Wind, biomass, hydroelectric, solar	http://www.dsireusa.org/documents/Incentives/VT03R.htm
	Interconnection Standards	Photovoltaics, wind, biomass, fuel cells, anaerobic digestion	http://www.state.vt.us/psb/rules/5100amendedappanoheader.pdf
	Renewable Portfolio Goal	Solar water heat, solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, anaerobic digestion, fuel cells (renewable fuels)	http://www.dsireusa.org/documents/Incentives/VT04R.htm
	Sales Tax Exemption	Solar water heat, photovoltaics, wind, biomass, anaerobic digestion, fuel cells (renewable fuels)	http://www.dsireusa.org/documents/Incentives/VT01F.htm
	Net Metering	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, anaerobic digestion, fuel cells (renewable fuels)	http://publicservice.vermont.gov/
Virginia	Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, tidal energy, wave energy	http://www.dsireusa.org/documents/Incentives/VA02R.htm
Washington	BEF - Renewable Energy Grant	Solar water heat, solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion	http://www.b-e-f.org/grants/renew_intro.shtm
	Fuel Mix Disclosure	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, municipal solid waste	http://www.dsireusa.org/documents/Incentives/WA04R.pdf
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, anaerobic digestion, small hydroelectric, tidal energy, wave energy, microturbines, other distributed generation technologies	http://www.wutc.wa.gov/energy
	Mandatory Utility Green Power Option	Solar thermal electric, solar thermal process heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, tidal energy, wave energy	http://www.wutc.wa.gov/greenpower
	Okanogan County PUD - Sustainable Natural Alternative Power Program	Photovoltaics, wind, biomass, renewable fuels	http://www.okanoganpud.org/conservation/snap.htm
	Sales and Use Tax Exemption	Solar water heat, photovoltaics, landfill gas, wind, biomass, fuel cells	http://www.dsireusa.org/documents/Incentives/WA04F.htm

State	Incentive	Eligible Renewable/Other Technologies	Incentive Website
	Washington Renewable Energy Production Incentives	Solar thermal electric, photovoltaics, wind, anaerobic digestion	http://northwestsolarcenter.org/5101%20q%26a.pdf
Wisconsin	Biobased Industry Opportunity (BIO) Grant Program	Biomass, renewable transportation fuels, anaerobic digestion	http://www.datcp.state.wi.us/mktg/business/marketing/val-add/biobased_industry_grants/index.jsp
	Focus on Energy - Grant Programs	Solar water heat, solar space heat, photovoltaics, wind, biomass, anaerobic digestion	http://www.focusonenergy.com/page.jsp?pageId=905
	Interconnection Standards	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, fuel cells, municipal solid waste, CHP/cogeneration, microturbines, other distributed generation technologies	http://psc.wi.gov/utilityinfo/electric/distributedGeneration/interconnectionProcedure.htm
	Public Benefits Fund	Solar water heat, photovoltaics, wind, biomass, anaerobic digestion	http://www.focusonenergy.com/
	Renewable Portfolio Standard	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, tidal energy, wave energy, fuel cells (renewable fuels)	http://www.dsireusa.org/documents/Incentives/WI05R.htm
	State of Wisconsin - Green Power Purchasing	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, tidal energy, wave energy, fuel cells (renewable fuels)	http://www.dsireusa.org/documents/Incentives/WI12R.pdf
	We Energies - Biogas Buy-Back Rate	Biomass, anaerobic digestion	http://www.we-energies.com/business_new/altenergy/custgen.htm
	We Energies - Renewable Energy Development Program	Solar thermal electric, photovoltaics, wind, biomass, anaerobic digestion, small hydroelectric, fuel cells (renewable fuels)	http://www.we-energies.com/business_new/altenergy/renewable.htm
	Net Metering	Solar thermal electric, photovoltaics, wind, biomass, hydroelectric, geothermal electric, municipal solid waste, CHP/cogeneration, other distributed generation technologies	http://www.we-energies.com/business_new/altenergy/custgen.htm
Wyoming	Interconnection Standards	Photovoltaics, wind, biomass, hydroelectric	http://www.dsireusa.org/documents/Incentives/WY02R1.htm
	Renewable Energy Sales Tax Exemption	Solar thermal electric, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric	http://www.dsireusa.org/documents/Incentives/WY04F.htm
	Net Metering	Photovoltaics, wind, biomass, hydroelectric	http://www.dsireusa.org/documents/Incentives/WY01R.htm

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14. ABSTRACT

Utilities privatization is considered the preferred method for modernizing and recapitalizing utility systems in the Army. From Fiscal Year (FY) 1998 to FY 2002, the Army implemented a Utilities Modernization Program that focused on upgrading thermal utilities (i.e., central heating and air-conditioning/refrigeration plants and the respective distribution systems) to the most life-cycle cost-effective technology. The current Utilities Modernization Program from FY08–13 will focus not only on central heating and air-conditioning/refrigeration systems, but also on electric, natural gas, potable water, and wastewater systems. This program is supported by initiatives/actions under the Army Energy and Water Campaign Plan for Installations. This report outlines a candidate program management strategy for the Utilities Modernization Program and outlines best practices for performing life-cycle cost analyses for central energy plants and each type of utility system either exempt from utilities privatization or pending exemption from privatization.

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