UFC 3-540-08
23 January 2017

UNIFIED FACILITIES CRITERIA (UFC)

UTILITY-SCALE RENEWABLE ENERGY SYSTEMS

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UNIFIED FACILITIES CRITERIA (UFC)

UFC 3-540-08 UTILITY-SCALE RENEWABLE ENERGY SYSTEMS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *DoD Building Code (General Building Requirements)*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET

Document: UFC 3-540-08, Utility-Scale Renewable Energy Systems

Superseding: None

Description: This UFC provides requirements for the planning, design, construction, and operations and maintenance of solar photovoltaic, horizontal axis wind turbine, waste to energy, landfill gas, and geothermal renewable energy power generation systems.

Reasons for Document:

- To provide unified Department of Defense renewable energy power generation criteria and create more consistency in DoD designs.

Impact:

This uniform effort will result in the more effective use of DoD funds in the following ways:

- Standardized guidance of utility-scaled renewable energy power production planning, design, construction, and operations and maintenance among the Services.
- Consolidation of utility-scaled renewable energy power technologies and summary requirements in UFC 3-540-08 allows Services to evaluate technologies and infrastructure needs to economically use available site specific resources.

Unification Issues:

- None

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This Unified Facilities Criteria (UFC) provides guidance for designing and installing renewable power generation (RPG) systems that interface with an installation's power grid. The criteria contained herein are intended to ensure durable, efficient, and reliable systems and installations. Whenever unique conditions and problems are not specifically covered by this UFC, use the applicable referenced industry standards and other documents for design guidance.

1-2 ORGANIZATION.

Chapter 2, *Planning and Development*, provides preliminary planning considerations for technologies applicable to installation location. Site attributes, including available space, topography, accessibility, location, and ecology, impact the technology selection. Chapters 3-7 provide additional details on each renewable power generation technology and Chapter 8 provides interconnection guidance.

1-3 APPLICABILITY.

This UFC applies to the planning, design, and construction, of utility scaled renewable energy facilities and installations, regardless of funding source. Per DoD Instruction 4270.5, the design criteria of this UFC do not apply to privatized housing or to projects acquired through a real property exchange agreement. This UFC also applies to overseas facilities, considering mission objectives and Host Nation standards, to the greatest extent practical.

Compliance with this UFC is mandatory for the design of renewable power generation systems that interface with an installation's power grid at all facilities and bases. This UFC applies to the creation of utility scaled power generation systems for installation power needs, and not for individual facility systems. For facility-level renewable energy systems, refer to UFC 3-440-01.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines, building systems, accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to the UFCs and government criteria referenced therein.

1-5 ENERGY RESILIENCE.

All energy systems must be planned, designed, acquired, executed, and maintained in accordance with DoD Instruction 4170.11, Installation Energy Management, and as required by individual Service and Defense Agency policies on energy resilience.

1-6 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06 and as required by individual Service Implementation Policy.

1-7 COPYRIGHT RELEASES.

National Renewable Energy Laboratory (NREL) developed maps and charts are not to be used to imply an endorsement by the NREL, the Alliance for Sustainable Energy, LLC, the operator of NREL, or the U.S. Department of Energy.

Use of energy associations' and organizations' data and references does not imply any DoD endorsement. Use of associations' and organizations' data is subject to individual terms of use.

1-8 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance of the reference is used.

1-9 GLOSSARY.

Appendix G contains acronyms, abbreviations, and terms.

CHAPTER 2 PLANNING AND DEVELOPMENT

2-1 INTRODUCTION.

This chapter provides preliminary planning considerations for renewable power generation technologies applicable to the installation location. Site specific attributes, including resource quality, space availability, topography, site location and accessibility, and ecology, impact the technology selection.

2-2 TECHNOLOGY SELECTION.

Installation location is a significant factor that governs which renewable energy sources are available for economic power generation development.

NREL provides dynamic resource maps, graphic information system data, and analysis tools for preliminary evaluations. The National Resources Conservation Service (NRCS) provides annual precipitation in the lower 48 states. Higher annual precipitation indicates increased biomass potential. National Oceanographic and Atmospheric Administration (NOAA) provides current and historical severe weather data for planning and design considerations. Review current resource maps and data for preliminary site analysis and planning only. Additional selection considerations are provided in individual RPG technologies chapters.

- NREL: http://www.nrel.gov/gis/re_potential.html
- NRCS: http://www.wcc.nrcs.usda.gov/climate/prism.html
- NOAA: https://www.ncdc.noaa.gov/data-access/severe-weather

2-3 CAPACITY FACTORS.

Capacity factor is a representation, in percent, of a generator's actual energy production divided by the generator's maximum power that it is rated to produce at continuous full power operation during the same period. For illustration, a one (1) megawatt (MW) generator at a 50% capacity factor produces 4,380 MW hour (MWh) of power annually (1MW x 50% capacity x 8,760 hours/year).

Waste to Energy (WTE), Landfill Gas (LFG), and geothermal plants are more stable power producers than solar or wind, whose generation capacity can vary significantly during any given hour due to clouds, gusts, and other environmental effects. Table 2-1 provides a summary of historical generation capacity factors, based upon Jan 2013-Feb 2015 data available from U.S. Energy Information Administration. Understand and account for the limiting factors and availability associated with each technology when determining an installation's overall energy supply portfolio.

Table 2-1 Generation Systems Capacity Factors

Technology	Capacity Factor Range		
	Low	Median	High
Solar Photovoltaic (PV)	15.6%	27.8%	32.0%
Wind	28.0%	33.1%	43.1%
Geothermal	67.3%	71.2%	76.8%
Solid Waste and LFG	61.4%	68.9%	72.4%

2-4 PLANT LOCATION FACTORS.

2-4.1 Siting Considerations.

Use the joint Natural Resources Defense Council / DoD primer, *Working with the Department of Defense: Siting Renewable Energy Development*, to screen renewable energy development, generation, or transmission sites.

2-4.2 Transmission Infrastructure.

The North America transmission system is monitored and controlled by the *Independent Systems Operators/Regional Transmission Operators* (ISO/RTO) (http://www.isorto.org). Bulk system reliability is under the *North American Electric Reliability Corporation* (NERC) (www.nerc.com) jurisdiction. Compliance with applicable NERC and ISO/RTO standards and requirements is mandatory. Coordinate with the applicable ISO/RTO for RPG system for transmission grid information, connection requirements, and future grid expansion.

Evaluate and address any gap(s) between the transmission infrastructure at/near the RPG site(s) and the required infrastructure/right of ways necessary to connect to installation's grid. Coordinate with the local ISO/RTO or the ISO/RTO Council, for smart grid connection requirements and ISO/RTO areas of responsibilities. Comply with Chapter 8 “UTILITY INTERCONNECTION” requirements.

2-4.3 Site Acreage Requirements.

Renewable energy power generation requires an extensive footprint. Actual site requirements are a function of location, system configuration, resource quality, and system efficiency as shown by the standard deviation column in Table 2-2. For initial planning purposes, use NREL average values as presented in Table 2-2 for initial RPG acreage planning factors, unless more actuate local data is available. For photovoltaic (PV) systems, the minimum footprint requirement can be calculated with the following formula:

$$A(\varphi) = 0.00205 \cdot \varphi^2 + 0.0493 \cdot \varphi + 2.21$$

Where: *A* is area in acres and φ is latitude in degrees North.

Table 2-2 Renewable Power Systems Footprints

Technology Type	Size (acres / MW) (tons / MW for LFG)	Size Std. Dev.(acres / MW)
Photovoltaic 1 – 10 MW	6.1	1.7
Wind 1 – 10 MW	44.7	25.0
Biomass Combustion Combined Heat and Power	3.5	1.9
Geothermal	1.6	-
Landfill Gas (LFG)	7900 tons/MW[1] (7200 metric ton/MW)	

[1] For planning purposes, use tonnage or gate-yard receipts, if available. Six gate-yards is approximately one ton of MW. If receipts not available, compacted landfill density ranges from 750-1,250 pounds per CY.

2-5 LOAD REQUIREMENTS.

2-5.1 Electrical Load Considerations.

Determine desired peak and annual power generation requirements. Address 24-hour and annual load considerations, and capacity factors associated with the evaluated RPG system. Account for RPG plant operational loads that reduce power transmitted to the grid.

2-5.2 Cogeneration Considerations.

Consider installation needs for secondary use of waste heat generated.

2-5.3 Energy Storage Considerations.

Consider thermal storage for off-generation use of thermal energy. Consider energy storage systems for power management of solar and wind systems. Energy storage is classified by its energy form: mechanical, chemical, electrochemical, thermal, magnetic, or electric field. Commercial utility scaled energy storage technologies in use include pumped hydroelectric (significant majority of U.S. capacity), compressed air, and conventional battery. Other technologies in use, and in development, include capacitors, flywheels, high temperature and flow batteries, superconducting, thermal storage, hydrogen, and potential energy systems.

2-5.4 Capacity Factors.

Account for capacity factors in project planning, and installation microgrid and islanding strategies. Use solar or wind power generation as a complementary power source, not as the sole primary power replacement option, unless a suitable storage technology is being utilized to provide power when solar and wind are not available.

2-6 UTILITY INTERCONNECT.

Individual states may have power connection limits. The Database of State Incentives for Renewables & Efficiencies (DSIRE) website, www.dsireusa.org, provides a summary of State interconnection policies and applicable State contact information. Coordinate with applicable State offices, local power company, and the ISO/RTO for limits and interconnection requirements. Comply with Chapter 8 titled “UTILITY INTERCONNECTION” requirements and IEEE 1547.

2-7 METERING.

Comply with the local utility company’s metering requirements as well as the OUSD (AT&L) *Utilities Metering Policy* as detailed in the following website: (http://www.acq.osd.mil/eie/IE/FEP_Policy_Program_Guidance.html) and DoDI 4170-11 Installation Energy Management.

2-8 SITE SPECIFIC DESIGN PLANNING.

2-8.1 Seismic.

Comply with UFC 1-200-01, including all referenced criteria and standards.

2-8.2 Topography.

Evaluate topography for system interferences and optimization, flood plains, and accessibility during planning, construction, and operation.

2-8.3 Site Access.

Evaluate transportation routes to site for accessibility for oversized loads and weights. Evaluate routes for impact and costs from construction traffic and loading. Ensure adequate laydown area is available during construction period and service roads to sites and supporting structures are provided.

2-8.4 Safety.

Comply with UFC 1-200-01 and UFC 3-600-01 for fire and life safety compliance.

2-8.5 Environmental.

Evaluate environmental requirements (e.g. noise, air pollution, wildlife, storm water) developed during the initial project planning stages in accordance with the National Environmental Policy Act NEPA.

2-8.5.1 Site Suitability

Confirm site is suitable for construction without major environmental impacts (e.g. are wetlands present?, is the ground contaminated?, endangered species?, etc.). If environmental concerns are present, survey and evaluate if they can be economically mitigated to meet applicable regulatory requirements.

2-8.5.2 Surveys

Field verify, through environmental, ecological, and biological surveys, that project's environmental impact will be minimal and can economically mitigated, if present.

2-8.5.3 Permitting

Once all environmental impacts have been assessed, then the actual permitting can begin. Permitting that is required by local and federal law has to address the renewable energy project construction and operational phases.

2-8.5.4 Compliance

All design and construction will provide electrical systems which must comply with Federal, State, and local environmental regulations. For overseas locations, follow the guidance specified in Host Nation-specific Final Governing Standards, or if none exists, the current DoD Overseas Environmental Baseline Guidance Document (OEBGD) and applicable Host Nation laws. For Air Force, consult AFI 32-7006 for additional guidance.

2-8.6 Environmental Studies and Permitting.

Plan for a permitting process that may take years, with duration depending upon the selected system and the locality (country, State, county and municipality) that is jurisdictionally responsible. Studies and permitting requirements exist at all levels (Federal, State, and local) and may include:

- 316(a) – Thermal discharge;
- 316(b) – Cooling water intake;
- Air permitting;
- Aquatic ecology;
- Avian and bat studies/protection;
- Cultural resources;
- Disposal (ash, slag);
- Dredge and fill;
- Encroachment;
- Erosion and sediment control;
- Floodplain management;
- Lake management;

- Land and right-of-way grants;
- Native American consultation;
- Natural resources;
- National Environmental Policy Act (Environmental Assessments (EAs), Environmental Impact Studies (EISs))
- Noise/Odor;
- River crossing permits;
- Threatened and Endangered species;
- Transmission line routing;
- Stormwater / Water quality; and
- Wetlands permitting, mitigation and design

2-8.6.1 Typical Permitting Process.

The next phase of a typical permitting process, after identifying all required permits, consists of the following six stages.

2-8.6.1.1 Stage 1 Pre-application.

Pre-application may take a few days to a year prior to filing a permit application. During this phase, developer and permitting agencies should meet to help ensure that both understand the project concept, permitting process, and possible issues. Make sure no gaps exist to minimize project schedule delays.

2-8.6.1.2 Stage 2 Permit Development and Submittal.

Complete all permit applications thoroughly, honestly, and timely. Use professional environmental consultants or attorneys if complexity of project warrants.

2-8.6.1.3 Stage 3 Application Review.

Activities vary, depending upon the agency reviewing the applications. Expect requirements for public sessions, meetings, and site visits to allow for discovery and alternative/modifications.

2-8.6.1.4 Stage 4 Decision Making.

Reviewing agencies will provide a decision with compliance requirements. This phase likely requires public hearings.

2-8.6.1.5 Stage 5 Administrative and Judicial Review.

If the decision is contested, the first avenue of appeal is administrative and it is directly to the decision maker. If the administrative appeal is not granted, the second stage is judicial review to assess if decision was fairly executed within accepted legal procedures.

2-8.6.1.6 Stage 6 Permit Compliance.

This phase is the final stage and extends throughout the project's lifetime including construction inspection and monitoring; operation; and decommissioning, to ensure project complies with all the terms and conditions of its permit and applicable laws.

2-8.6.2 Federal and State Policies and Incentives.

The DSIRE website provides a convenient source for Federal and State renewable energy policies and incentives. Review and address policies applicable to the site, and incorporate available incentives into economic analysis.

2-8.7 Industrial Control Systems and Network Risk Management.

Information systems connected to, or software loaded onto DoD information grids, must receive an interim or full authorization to operate/test prior to connection to the DoD information grid in accordance with UFC 4-010-06 and as required by individual Service Implementation Policy.

2-9 COST FACTORS.

Provide project life cycle cost analysis. NREL provides summary costs charts for RPG at http://www.nrel.gov/analysis/tech_cost_dg.html. Chart data is from U.S. Department of Energy (DoE) Federal Energy Management Program (FEMP).

Note: The cost factors referenced in the NREL site are representative of an average commercial acquisition, and may not reflect the cost factors associated with Federal government acquisition methodologies.

2-9.1 System Useful Life.

Use Table 2-3 for initial planning factors and life cycle cost analysis.

Table 2-3 Renewable Power System Useful Life

Renewable Power System	Useful Life
Photovoltaic Cells	25 to 40 yrs.
Inverters	10 yrs.
Wind	20 yrs.
Biomass Combined Heat and Power	20 to 30 yrs.
Biomass Heat	20 to 30 yrs.

2-9.2 Historical Capital and Operations and Maintenance (O&M) Costs.

RPG capital, operation, and maintenance costs are highly dependent upon location and plant size. Use The NREL average Table 2-4 costs for solar, wind, and biomass combustion systems for initial cost planning purposes.

Table 2-4 NREL Distributed Generation Renewable Energy Installed Costs

	Generator Type / Size System		
	PV 1–10 MW	**Wind 1–10 MW**	**Biomass Combined Heat & Power***
Mean installed cost $/kW	$2,667	$2,644	$6,067
Installed cost Std. Dev +/- $/kW.	$763	$900	$4,000
Fixed O&M $/kW-yr.	$20	$36	$91
Fixed O&M Std. Dev. +/- $/kW-yr.	$10	$16	$33
Variable O&M $/kWh	n/a	n/a	$0.06
Variable O&M +/- $/kWh	n/a	n/a	$0.02
Lifetime yr.	33	20	28
Lifetime Std. Dev. yr.	9	7	8
Fuel or water cost $/kWh	n/a	n/a	$0.04
Fuel or water Std. Dev. $/kWh	n/a	n/a	$0.02

*Unit cost is per kilowatt of the electrical generator, not the boiler heat capacity.
Geothermal cost breakdown not available. See Appendix F for planning factors and cost models.
Costs are NREL update of August 2013.

2-9.3 Levelized Cost of Energy.

Table 2-5 illustrates projected ranges of cost to produce a MWh of energy, by generation technology/energy source, before incentives are included. Both renewable and non-renewable systems are provided as a reference. As renewable energy technologies improve, their levelized cost of energy may become very competitive with or exceed most traditional energy sources.

Evaluate and make preliminary RPG system selections based upon current energy costs, quantifiable and non-quantifiable benefits to mission, and system life cycle cost. More cost effective renewable systems may not be suitable for specific installation or mission requirements. NREL website, http://www.nrel.gov/analysis/tech_lcoe.html, provides a planning calculator for levelized cost of energy.

Table 2-5 Levelized Cost of Energy

Regional Variation in Levelized Cost of Electricity (LCOE) for New Generation Resources, On Line Starting 2020 Range for Total System LCOE (2013 $/MWh) w/o subsidies			
Plant type	**Minimum**	**Average**	**Maximum**
Renewable			
Geothermal	$ 43.80	$ 47.80	$ 52.10
Biomass	$ 90.00	$ 100.50	$ 117.40
Wind	$ 65.60	$ 73.60	$ 81.60
Solar PV	$ 97.80	$ 125.30	$ 193.30
Conventional			
Conventional Coal	$ 87.10	$ 95.10	$ 119.00
Advanced Coal	$ 106.10	$ 115.70	$ 136.10
Advanced Coal with CCS*	$ 132.90	$ 144.40	$ 160.40
Natural Gas-fired			
Conventional Combined Cycle	$ 70.40	$ 75.20	$ 85.50
Advanced Combined Cycle	$ 68.60	$ 72.60	$ 81.70
Advanced CC with CCS*	$ 93.30	$ 100.20	$ 110.80
Conventional Combustion Turbine	$ 107.30	$ 141.50	$ 156.40
Advanced Combustion Turbine	$ 94.60	$ 113.50	$ 126.80
*CCS Carbon Control and Sequestration			

2-10 FUNDING SOURCES AND ECONOMIC ANALYSIS.

DoD funding is very limited for large scale RPG. One funding program is the Energy Conservation Investment Program (ECIP). Execution is through the standard construction contract mechanisms.

Third party funding options include Power Purchase Agreements (PPA) and Enhanced Used Lease (EUL)/out grant/leases. Energy Savings Performance Contracts (ESPCs) and Utility Energy Service Contracts (UESCs) are financed contracting options which do not require DoD funding upfront. Additionally, ESPCs provide risk mitigation through performance guarantees and contracted O&M and repair and replacement services (beyond just warranty period services) for the financed contract term up to 25 years. Energy savings in UESCs are stipulated by the Utility as well as the Government. O&M, repair, and replacement services can be included; however, the contract term is most often shorter.

2-10.1 Power Purchase Agreement (PPA).

Under a PPA, a developer typically installs a renewable energy system on agency property under an agreement that the agency will purchase the power generated by the system. However, in some cases the renewable energy system can be installed on property owned by the developer and the energy production can be delivered either behind the meter through the base distribution system or ahead of the meter through the commercial grid into the base distribution system. After installation, the developer owns, operates, and maintains the system for contract life.

2-10.2 EUL/Out Grant/Leases.

Title 10 USC § 2667, gives DoD the authority to enter into long-term and short-term leases for non-excess DoD controlled land or facilities.

Evaluate In-Kind Consideration and the Deposit and Use of Proceeds from EUL/out grant/leases in accordance with 10 USC § 2667, Office of the Under Secretary of Defense Financing of Renewable Energy Projects Policy, and other associated directives.

2-10.2.1 Energy EUL/Out Grant/Leased Facility.

An energy EUL/out grant/leased facility may be designed and operated completely independent from an installation's power grid, that is, generated energy is transmitted to the commercial grid. In this configuration, the facility is typically designed and operated in accordance with commercial specifications, agreements, and contracts between the utility and the private sector developer. The facility is not designed for Government use or occupation, so UFC compliance is limited to interoperability, safety, and security requirements.

Consideration from energy EUL/out grant/leases may include capabilities that enable installation energy security or fund specific energy initiatives. In this configuration, the facility is generally designed and operated in accordance with commercial specifications, but also includes certain interfaces with an installation's power grid. Ensure these interfaces are compatible with the paragraph titled "GENERAL COMPLIANCE REQUIREMENTS" in Chapter 1.

2-10.2.2 EUL/Out Grant/Lease Objective.

EUL/out grant/lease program's primary objective is to optimize the value of non-excess properties in accordance with Executive Order 13327, which promotes the efficient and economical use of America's real property assets. Demonstrating and documenting that a proposed out grant/lease is technically and economically viable and compliant with applicable statutory authorities is the responsibility of each Service. Economic and technical analysis, mission compatibility and other out grant/lease project specific due diligence is conducted in accordance with Service specific out grant/lease Playbooks, Instructions and Directives.

Contact Service leads for additional EUL/out grant/leased information and requirements:

- Army: http://www.nab.usace.army.mil/Businesswithus/realestate/EUL.aspx
- Air Force: http://www.afcec.af.mil/EUL/

2-10.3 Additional Cost Considerations.

Include operations and maintenance, decommissioning, and site restoration costs in economic analysis.

2-10.4 Economic Analysis.

Use UFC 3-730-01, UFC 3-740-05, applicable design agency guidance, and installation policies and procedures.

2-11 COORDINATION.

2-11.1 Office of the Secretary of Defense (OSD) Coordination.

32 CFR Part 211 requires OSD to conduct mission compatibility evaluation of proposed projects. Request a preliminary determination from the OSD Clearing House (website: http://www.acq.osd.mil/dodsc/) at osd.dod-siting-clearinghouse@mail.mil once preliminary details are available.

A formal review is mandatory for projects filed with the 49 USC Section 44718, as well as other projects proposed for construction within military training routes or special use airspace, whether on private, State, or Federal property, such as Bureau of Land Management lands. See http://www.acq.osd.mil/dodsc/ for specific data and reporting requirements.

2-11.1.1 Airspace Coordination.

Comply with UFC 3-260-01 when evaluating renewable power generation systems and equipment siting near an airfield or related facilities and equipment used to sustain flight operations. Provide applicable data items required for the OSD coordination. Submit plans to site renewable power generation systems and equipment near an airfield to the Airfield Manager and Safety Officer for approval.

2-11.1.2 Military Training Route and DoD Siting Clearinghouse.

The Military Training Route (MTR) program is a joint venture by the Federal Aviation Administration (FAA) and the DoD to develop routes for the purpose of conducting low-altitude, high-speed testing, and training activities. Improper site planning can negatively affect the MTR program. Contact the DoD Siting Clearinghouse (http://www.acq.osd.mil/dodsc/) during initial planning, and prior to applying for permits on any Federal or non-Federal lands, for project site vetting. Provide applicable data items required for the DoD Siting coordination.

2-11.1.3 FAA Requirements.

FAA requires early planning coordination for structures and assessment of glare from solar panels. For structure assessment, complete FAA Form 7460-1. Glare assessments are covered under FAA interim policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports. This interim policy requires use of the

Solar Glare Hazard Analysis Tool (SGHAT). Provide both FAA Form 7460-1 and SGHAT report to the DoD Siting Clearinghouse. SGHAT registration located at: www.sandia.gov/glare. Coordinate international sites through the DoD Siting Clearinghouse to ensure International Civil Aviation Organization (ICAO) requirements are addressed.

2-12 PROGRAMMING.

Use Table 2-6 to determine primary Category Codes for RPG projects. No geothermal Category Code currently exists.

Table 2-6 Category Codes

	PV	Wind	WTE	LFG
Air Force	811145	811146	811145	811145
Army	81122	81146	81113	81117
Navy	81150	81146	81125	81145

CHAPTER 3 DESIGN CRITERIA - PHOTOVOLTIAC (PV) SYSTEMS

3-1 INTRODUCTION.

This chapter identifies typical applications and defines the data that must be developed to establish engineering design bases, to evaluate between various solar PV designs, and ownership alternatives for utility scaled PV systems (system output greater than 1 MW).

3-1.1 Technology.

Solar PV technology generates direct current (DC) electrical power from semiconductors when they are excited by the sun. DC power is converted into alternating current (AC) through inverters and voltage stepped up for transmission.

3-2 PLANNING.

If not previously established, create an energy capacity plan covering the installation's planning vision, goals, and objectives to identify the system power and operational requirements. Coordinate plan with the system owner and utility provider to allow a comprehensive economic and site selection evaluation. Ensure economic analysis includes currently available local, state, and Federal incentives. Complete an environmental impact study to ensure project site is viable.

3-2.1 DoD Siting Clearinghouse.

Perform proposed and final siting coordination with OSD. 32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination with OSD is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil to avoid invalid site selections.

3-2.2 Climatic Zones.

Basic engineering practices governing design and construction of electrical power systems in arctic and subarctic zones will comply with agency criteria and UFC 1-200-01. Refer to UFC 3-440-05N (for Navy). For other Agencies, use UFC 3-440-05N as a reference and comply with Agency specific guidance for design and construction of electrical power systems in temperate areas.

3-2.3 Permitting.

Comply with paragraph titled "DESIGN APPROVALS AND PERMITS" in UFC 3-201-01 for permitting requirements.

3-2.4 Interconnection Analysis and Coordination.

Contact the local utility provider for utility-specific interconnection equipment and ownership requirements in the design concept stage due to utility-specific requirements. Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

3-3 DESIGN CRITERIA.

Address mounting systems, solar PV modules, raceways and DC cabling, system grounding, lightning protection system, surge protection, raceway and AC cabling, metering, system criteria and selection, interconnections, warranty requirements, and site maintenance considerations in the design.

3-3.1 Structural Components.

Comply with UFC 1-200-01, including all referenced criteria and standards for all structures and structural elements, including PV array structures.

3-3.1.1 Mounting Systems.

Mounting systems are either active or fixed tracking. Select mounting system appropriate for site conditions and project requirements. Evaluate the cost verses power generation benefit of using an active tracking system over a fixed tracking system. Include initial and operation and maintenance costs in the cost analysis.

3-3.1.2 Ground Mounting.

Comply with UFC 3-301-01 for requirements related to the foundation, soil stability, and seismic analysis. Use ground mounting systems of the same manufacturer for the entire project array. The system must withstand the expected wind loads for the location. Complete an environmental impact assessment for the site. Foundation must be either concrete, concrete pad ballast, driven pile, or helical pile.

3-3.1.3 Tracking Array System.

Design for solar PV tracking system in accordance with IEC 62727.

3-3.1.4 Array Tilt Angle.

Tilt the array to the latitude plus or minus 10 degrees. It should be noted that as the tilt angle increases, the minimum spacing between rows must be increased due to shading. Do not allow inter-row shading between 9 a.m. and 3 p.m., when the bulk of the energy collection occurs.

3-3.1.5 Array Azimuth Angle.

For optimum performance, orient the module true south in the northern hemisphere and true north in the southern hemisphere; however, slightly west of south or north (azimuth angle of true south or north plus 10 degrees) may be preferable in some locations if an early morning haze or fog is a regular occurrence. Design the array's azimuth angle off of due south or north as coordinated with the Basis of Design.

3-3.1.6 Site.

Account for shading, grounds maintenance requirements, and winter snow levels when determining mounting heights, spacing, and ground cover. Closed landfill sites require non-penetrating foundations to avoid breaching cap.

3-3.2 Direct Current (DC) System Components.

3-3.2.1 Solar PV Module.

Conform to UL 1703 and IEC 61215 for crystalline types, or IEC 61646 for thin film types. Require submission of manufacturer's guarantee on backsheet and encapsulant construction. Select one commercially-available PV module type based on life cycle cost analysis, required energy production, site location environmental conditions, space available, and maintainability.

3-3.2.2 Solar PV Array.

Comply with National Fire Protection Act (NFPA) 1 for array arrangement requirements.

3-3.2.3 Raceway and DC Cabling.

Provide UL 4703 listed PV wiring. Comply with UFC 3-501-01 for requirements related to raceway and DC cabling sizing.

3-3.2.4 Combiner Box.

Provide UL 1741 listed combiner box.

3-3.2.5 DC Switching.

If stand-alone unit, DC disconnect switches must conform to UL 98 or UL 98B. Rate switch for maximum system voltage and maximum system continuous and short circuit currents. If combined with inverter, refer to paragraph entitled "Inverter" for guidance.

3-3.2.6 Inverter.

Conform to UL 1741, comply with IEEE 1547 and NFPA 70, and be identified for use in solar PV power systems for allowance of monitoring. The selection of inverter type, i.e. central, micro-inverter, or string inverter, will depend on the system size, budget, and site-specific parameters. Consider use of inverters with integral medium voltage transformers. Place inverters in location to allow for adequate air circulation. Where possible, employ maintainable design practices when selecting number of inverters for project to prevent the failure of one inverter from affecting the entire system. Limit inverter sizes to 750 kW maximum, with a minimum 95% efficiency.

3-3.3 Alternating Current (AC) System Components.

3-3.3.1 Transformer.

Provide transformers in accordance with IEEE Std 1547 and NFPA 70. Provide primary and secondary over-current protection in accordance with NFPA 70. Refer to UFC 3-520-01 and 3-550-01 for additional requirements. Use USACE ETL 1110-3-412 (Army only) as a reference for the selection and application of transformers and dielectrics. Ensure transformer and separately derived systems installation strictly comply with NFPA 70, Article 250.

3-3.3.2 Raceway and AC Cabling.

Provide UL 4703 listed PV wiring. Raceway and AC cabling sizing must conform to UFC 3-520-01 and NFPA 70. Install all cabling in raceways unless specifically indicated otherwise.

3-3.3.3 AC Switching.

Rate switch for maximum system voltage and maximum system continuous and short circuit currents. If stand-alone unit, AC disconnect switches must conform to UL 98 or UL 98B. If combined with inverter, refer to paragraph entitled “Inverter” for guidance.

3-3.3.4 Metering.

Coordinate revenue metering requirements with the utility provider and DoD installation regarding interconnection-specific data and guidelines. Coordinate with Activity and utility provider for requirements and plan of action to manage excess energy, including the utilization of net metering.

3-3.3.5 System Monitoring.

Provide system monitoring in accordance with IEC 61724. Provide features to transmit real time system and status data to an energy information system (via network system assets or cellular technology).

3-3.4 Grounding and Lightning Protection.

3-3.4.1 System Grounding.

Grounding is a common system failure point. Strictly comply with UFC 3-550-01, NFPA 70, and IEEE C2 for requirements related to general system grounding.

3-3.4.2 Lightning Protection System.

Provide surge protection in accordance with NFPA 780. Comply with UFC 3-520-01 for requirements related to providing a lightning protection system. Provide side flash calculations as required by NFPA 780.

3-3.4.3 Surge Protection.

Provide surge protection devices for all systems identified in NFPA 780 and UFC 3-575-01. Show location of all surge protective devices on drawings.

3-3.5 Climatic Considerations.

Design system to operate under the location's maximum and minimum documented temperatures during summer and winter. Account for snow depths and known snowdrift patterns when determining locations and mounting heights in Snowbelt locations.

3-3.6 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

3-4 OPERATION AND MAINTENANCE.

Maintenance considerations consists of two categories: scheduled/preventive maintenance and unscheduled maintenance/troubleshooting. Treat solar PV equipment with the same caution and care as regular electrical power service equipment. Comply with the requirements of UFC 3-560-01 and manufacturers' documentation, as required. Refer to Appendix E for additional O&M guidance.

3-4.1 Preventive Maintenance.

Preventive maintenance scheduling and frequency is dictated by a number of factors including, but not limited to, technology selected, site environmental conditions, warranty terms, and seasonal variances. Conduct scheduled maintenance at intervals in accordance with the manufacturers' recommendations, as required by equipment warranties, and at times to reduce production impacts.

3-4.2 Unscheduled Maintenance.

Unscheduled maintenance, or troubleshooting, is carried out in response to equipment failures. Refer to manufacturer's system documentation for troubleshooting steps for the failed components.

It is important to maintain an adequate supply of spare components in stock to facilitate rapid response times. The number of required spares depends on the system size, site-specific parameters, parts availability, budget, and desired system availability (reliability).

3-4.3 Safety.

Comply to applicable provisions in 29 CFR 1910, 29 CFR 1925, and 29 CFR 1926, and local/agency codes and requirements.

3-4.4 Warranty.

Specific system components warranties vary by manufacturer. PV module warranty typically ranges from 5-10 years with top brand providing 20 to 25 year warranty. Performance warranty is based upon minimum continuous power output of 80 percent at typically 20 years. Inverter warranties average from 5-10 years, dependent upon manufacturer and technology. PV mounting system warranty typically varies between 5-10 years.

Require a minimum of a five (5) year Contractor parts and labor warranty for component failure due to workmanship, defective components or assemblies on the entire solar PV system, regardless if the component manufacturers are still in business or not. Include warranty costs in the economic analysis.

3-4.5 Security.

Comply with UFC 4-010-01 and UFC 4-020-01 for security concerns, theft and vandalism protection, and unauthorized area entry.

CHAPTER 4 DESIGN CRITERIA – WIND SYSTEMS

4-1 INTRODUCTION.

This chapter presents the planning, design, and O&M requirements for renewable energy produced by a wind driven utility scaled (greater than 1 MW total output) horizontal axis wind turbines (HAWT).

4-1.1 Technology.

Two primary wind turbine configurations exist: HAWT and vertical axis wind turbine (VAWT).

4-1.1.1 HAWT.

HAWT configuration has the rotor blades' plane perpendicular to the wind direction and with the axis of main rotor shaft rotation lying in the horizontal plane. HAWTs are the most widely used turbine technology utilized in the world.

HAWT systems with a minimum of three (3) years of proven commercial power generation are generally approved for use in the DoD for utility-scaled power generation.

4-1.1.2 VAWT.

VAWT configuration has the main rotor shaft axis of rotation lying in the vertical plane. VAWTs have minimal utility-scale power generation history.

VAWTs are not approved for use in the DoD for utility-scaled renewable power generation.

4-1.2 Application.

Large commercial and utility-scale wind turbines (0.5 - 7.5 MW) are generally grouped in wind 'farms' for producing power plant scale energy for sale. The increased efficiency and high availability rates for these systems allow for cost-competitive electricity generation. Due to the height, size, and land requirements for utility-scale wind power generation, projects require extensive environmental, utility, and public coordination, detailed site resource assessments, legal and financial due diligence, utility integration, and financial analysis planning before project execution.

4-2 PLANNING.

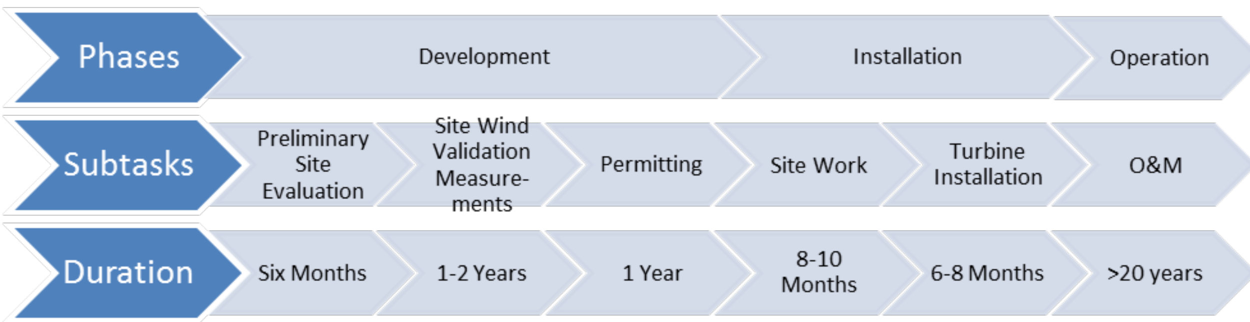
4-2.1 DoD Siting Clearinghouse.

Perform proposed and final siting coordination with OSD. 32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination with OSD is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil to avoid invalid site selections.

4-2.2 Wind Farm Project Development.

ASCE/AWEA RP2011 provides a planning flow chart for a typical commercial wind farm project, from initial site evaluation through operation that will aid wind farm planners. A wind farm project may take up to four years from concept to full production. Figure 4-1 provides typical project timeline.

Figure 4-1 Wind Turbine Typical Project Timeline



4-2.3 Site Selection.

4-2.3.1 Adequate Wind Resources.

DoE Energy Efficiency & Renewable Energy (EERE) web site provides utility scale wind resource maps. Use the 260 ft. (80 m) wind resource map for initial planning considerations for commercial power generation. Localized site data is also available from commercial sources. Once initial planning indicates viable wind resources are available, a site-specific wind study is required to categorize wind energy characteristics for feasibility analysis.

4-2.3.2 Transmission Lines.

Perform transmission study to evaluate, as a minimum, line proximity, available line capacity, reliability, and connection costs. Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

4-2.3.3 Site Footprint.

Use Table 2-2 for initial site size planning factors. Turbine(s) layout depends upon site’s topography, site boundaries, exclusion zones, and setback/buffer zones. Layouts are typically either linear (single or multiple strings, or parallel) or clustered. Wind turbines are typically not sited within five (5) rotor diameters of each other. Require computational optimization of turbine layout, as a little as 1% improvement in efficiency provides a significant long-term energy production benefit.

Account for acreage required for short-term (construction) and long-term (operations). Identify and address staging and lay down areas and impacts during planning. Estimate short-term site impact as twice the acreage as the final operation area boundaries. Identify final site layout to include operational areas, exclusion zones, safety zones, and buffers.

4-2.3.4 Site Access.

Account for the construction access for heavy and long/oversized loads. Perform delivery route analysis for roads, bridges, underpasses, inclines/declines, and overhead utilities.

4-2.4 Wind Assessment.

Perform a two-phase site wind assessment: 1) preliminary evaluation using historical data and 2) site specific analysis using meteorological towers to collect wind direction, speeds, and frequencies. If commercial financing is being sought for the project, an investment grade wind resource study is required to establish the quality, reliability, and value of the wind resource. Wind resource assessment guidance including a Wind Resource Assessment Handbook is available at the following National Renewable Energy Laboratory (NREL) website:
http://www.nrel.gov/wind/resource_assessment.html

4-2.4.1 Historical Data.

Historical wind data is available from NREL and commercial sources. Use historical data to perform preliminary site assessment. Sites with greater than 6 meters per second (m/s) average wind speed are considered viable.

4-2.4.2 Site Assessment.

Once site passes preliminary assessment using historical data, perform site specific wind analysis using meteorological towers. Quality of wind depends upon turbine location with respect to plains, buttes, ridges, facilities, and general topography roughness on the turbine’s windward site. If site topography varies significantly, more than one meteorological tower may be required to adequately characterize site’s wind potential. Perform site assessment for at least one year to account for seasonal changes.

Collect wind speed and direction using anemometers and wind vanes. Place sensors two or three heights (two anemometers and one vane per height) on the tower. Place top sensors as close to projected turbine hub height as possible to ensure more accurate power estimates. Use booms for sensors to reduce tower wake effects on wind data. Collect average wind speed and direction at 10-minute intervals.

4-2.4.3 Site Energy Projections.

Site wind speeds, frequencies, directions, and durations are utilized to generate power projections. Use collected wind data to generate site power production projections using specific wind turbines' power curves.

4-2.5 Community Concerns.

Early community involvement is critical for project success. Typical community concerns include generated sound, visual impacts to include blade flicker (shadows), and increased traffic during construction. Initiate a community outreach program early in the planning stage to ensure community concerns and requirements are known and mitigated early in the program development.

4-2.5.1 Sound.

The dominant noise-generating component of large-scale wind turbines is aerodynamic. Conduct baseline and predictive noise studies to generate maps of isophones to determine potential mitigation areas and for community discussions. Follow IEC 61400-11.

4-2.5.2 Visual.

Installation of 260 ft. (80 m), or higher, wind towers will change the site and surrounding areas visual aspect. Conduct a Zone of Visual Influence Study to calculate where the wind farm will be visual and to what extent. Conduct Worst-Case Scenario Study for shadow fluttering on surrounding occupied structures and active roadways. Mitigate negative findings by adjusting turbine siting, diameter, or height. Use studies to articulate impact with community and to analyze mitigation actions.

4-2.5.3 Traffic.

Construction and materials movement will affect local communities. Coordinate with local communities on routes, impacts, and timing.

4-2.6 Environmental.

4-2.6.1 Endangered Species.

Evaluate site for seasonal and year-round endangered species. Address and implement mitigation actions. Obtain permits and authorizations required under the Endangered Species Act of 1973 for activities that may take native threatened or endangered species. Contact nearest U.S. National Fish and Wildlife Service (USFWS) Ecological Services Office and determine if the proposed project is likely to result in "take," whether a permit is required, and if other options are required to be considered.

4-2.6.2 Avian and Bat Studies.

Conduct avian and bat study for projected impacts. Address recommendations and implement mitigation actions.

4-2.6.3 Historical, Cultural and Archeological Studies.

Evaluate site for historical, cultural, and archeological aspects. Address findings and implement mitigation actions.

4-2.6.4 Wetlands Reviews.

Conduct wetland reviews. Address findings and implement mitigation actions.

4-2.7 Federal Aviation Administration Coordination.

4-2.7.1 Flight Path Concerns.

The FAA has legal jurisdiction over structures 200 ft. (61 m) tall and above. Additionally, structures less than 200 ft. (61 m), but within 20,000 ft. (6 km) of a runway, may still penetrate navigable airspace. FAA evaluation starts with submitting FAA Form 7460-1. The FAA will issue either a Determination of No Hazard, or a Determination of Presumed Hazard, which may initiate a process of negotiation and appeal.

4-2.7.2 Radar Concerns.

Static electricity generated by the blades moving through the air may create radar ‘blind spots.’ The OSD and U.S. Air Force coordination with the FAA will analyze the site for conflicts and mitigation requirements, if required.

4-2.8 Interconnect Studies.

Designer must perform interconnect studies. Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

4-2.9 Permitting.

4-2.9.1 Land Use Permits.

Coordinate with OSD Clearinghouse and Bureau of Land Management for public lands, and State environmental and energy planning offices for land use permits.

4-2.9.2 Building Permits.

Comply with applicable city/State / Federal for building permits requirements.

4-2.9.3 Incidental Take Permit.

Obtain Incidental Take Permit in accordance with 50 CFR Part 13 and 50 CFR Part 17.

4-2.10 Economics.

4-2.10.1 Power Projections.

Require developer to provide life cycle power projections based upon site specific resource conditions, and turbine manufacturer and model.

4-2.10.2 Rate Structures and Terms.

Coordinate with local power company and ISO/RTO for installation site rate structures. Engage the following offices for utility term negotiations:

- U.S. Air Force: U.S. Air Force Civil Engineer Center, Energy Directorate (AFCEC/CN).
- U.S. Army: U.S. Army Engineering and Support Center, Huntsville, Energy Division, Commercial Utilities Program.
- U.S. Navy: Naval Facilities Engineering Command Headquarters, Public Works Business Line, Utilities and Energy Management, Washington Navy Yard, Washington, D.C. (NAVFAC HQ PW UEM).

4-2.10.3 Project Costs.

Installed costs fall under three categories, turbine cost, soft costs, and balance of station costs. For preliminary project estimation, use values in Table 2-4 and use the percentages in Figure 4-2 to estimate sub-factor capital costs.

4-2.10.4 Operations and Maintenance Contracts.

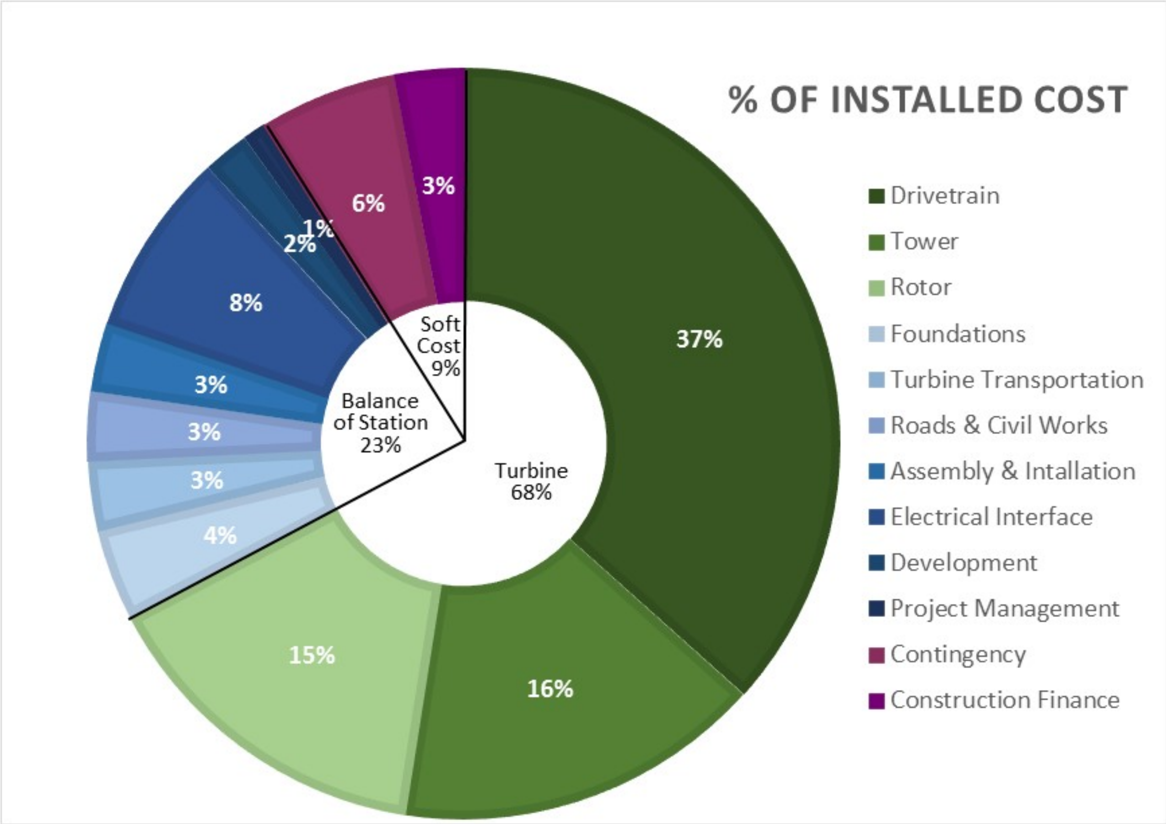
Use American Wind Energy Association's *Operations and Maintenance Recommended Practices* for O&M requirements in contract statement of works and basis for cost estimation.

4-2.10.5 Extended Warranties.

Estimated economical life of wind turbines is 20 years. Perform cost/benefit analysis to obtain extended equipment warranties versus cost of O&M contracts for the period between the standard warranty and the extended warranty.

Note: At end-of-life, wind turbines may be decommissioned and site restored; components refurbished; and/or replaced with new turbine systems, depending up economics and available technology. As a minimum, use similar end-of-life scenarios to determine economic differences between the selected options in the economic analysis.

Figure 4-2 Land Based Wind Turbine Systems Installed Capital Costs (AWEA)



4-3 DESIGN CRITERIA.

Primary wind industry design standards are codified under the International Electrotechnical Commission (IEC) IEC 61400 series. A lead wind association assisting in codifying U.S. standards is the American Wind Energy Association. Review both resources for current design requirements.

4-3.1 Wind Turbine System.

4-3.1.1 Classes.

Comply with IEC 61400-1. Table 4-1 represents IEC 61400-1 wind turbine classifications data. A class IIB wind turbine, for example, is designed for average wind conditions, at hub height, for 95 mph (42.5 m/s) with medium turbulence characteristics. Designer of Record to select the wind turbine class based upon site conditions.

Table 4-1 Wind Turbine Classes

Wind Turbine Class	I	II	III	S
Average wind speed over 10 minutes at hub height.	50 m/s (112 mph)	42.5 m/s (95 mph)	37.5 m/s (84 mph)	Values specified by designer
	Expected turbulence intensity at 15 m/s (33 mph)			
A – high turbulence characteristics	0.16			
B – med turbulence characteristics	0.14			
C – low turbulence characteristics	0.12			

4-3.1.2 Design Life.

Require wind turbine design lifetime for a minimum of 20 years.

4-3.1.3 Components.

Evaluate during site planning phase the individual wind turbine component shipping, site access, and lay down area requirements. Common blade lengths range from 100 – 165 ft. (30 – 50 m) long. Towers range from 195 – 260 ft. (60 – 80 m) high, but are typically shipped in three sections. Component lengths will eliminate certain road access routes. Heavy components, such as hubs which weight from 7 – 20 tons (6,350 – 18,147 kg), may eliminate bridge or road routes due to weight limits.

4-3.1.4 Structural Design.

Structural design, including foundations, to comply with ASCE/AWEA PR2011, as updated.

4-3.2 Electrical.

Figure 4-3 diagramically presents a wind farm electrical system and connection to transmission grid. Comply with current editions of UFC 3-501-01 and UFC 3-550-01. Comply with Chapter 8 titled “UTILITY INTERCONNECTION” and coordinate electrical system with host utility provider.

4-3.2.1 Grounding.

Comply with NFPA 70.

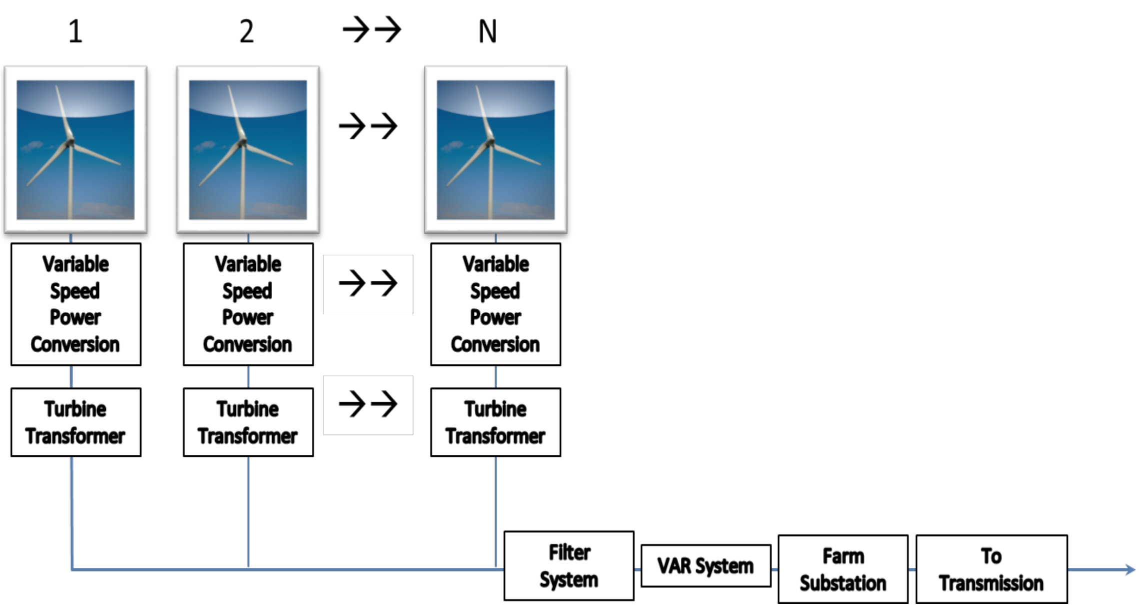
4-3.2.2 Lightning Protection.

Comply with IEC 61400-24 and NFPA 780.

4-3.2.3 Interconnection.

Comply with Chapter 8, titled "UTILITY INTERCONNECTION," IEEE 1547, and IEEE 519.

Figure 4-3 Illustrative Wind Farm Components



4-4 OPERATIONS AND MAINTENANCE.

4-4.1 Contract Based Operations and Maintenance.

O&M service contracts starts after the warranty period expires and are typically based upon a system operating life of 20 years. Contracts are based on either time (e.g. years) or amount energy produced. Address site and equipment O&M requirements and ensure O&M is available at turbine startup, either by warranty contract or by service contract. Appendix E provides additional O&M guidance.

Comply with specific turbine manufacturer's recommendations. Use predictive maintenance on high value components, such as yaw and pitch systems, gearbox, and generators. Perform annual infrared study on mechanical and electrical components. Use preventive maintenance on remaining components, such as structures and supporting infrastructure.

4-4.1.1 Turnover Inspections.

Perform a turnover inspection a minimum of three (3) months prior to warranty ending to identify and resolve warranty-based issues. Minimum inspection requirements include:

- Visual structural and component inspection;

- Qualitative checks on items such as bolting torque settings, component oil leaks, pitch linkage wear, cable routing, electrical terminations and installed safety equipment;
- Gearbox vibration monitoring;
- Oil sampling and analysis;
- Site-wide infrared analysis;
- Review of all service reports and parts usage during the warranty period; and
- Perform condition baseline inspection at start of O&M contract.

4-4.1.2 Monitoring.

Require 24-hour remote monitoring of wind turbine systems to include predictive maintenance sensors for key attributes, e.g. rpm, wind speeds, blade positions, vibration, temperature, fluid levels, power output.

4-4.2 Safety.

Establish safety and response plans for the following items:

4-4.2.1 Solid and Hazardous Wastes.

Address the transportation, handling, storage, and disposal of hazardous materials to and from site.

4-4.2.2 Ice Shedding.

Provide ice detection and shutdown response to reduce ice projection and blade imbalance. Conduct ice throw risk assessment to identify potential risks. Provide warning signs in impact zones to alert operational personnel of potential of falling ice.

4-4.2.3 Blade Failure.

Provide warning signs for potential blade impact zones, in case of a catastrophic blade failure.

4-4.2.4 Fire.

Create fire response plans and provide close coordination with and training for local firefighters. Train all on-site personnel on fire and emergency response plans. Adhere to regular and appropriate maintenance schedules.

4-4.2.5 Lightning Strikes.

Adhere to safety protocols including stopping work when thunderstorm warnings or watches are issues. Require annual training on awareness and evacuation procedures.

Identify site designated shelter and provide lightening prediction and warning system, with communications, to maintenance team.

4-4.2.6 Worker Fall Protection.

Compliance with work fall protection standards is critically important due to wind turbine heights and operating environment. Comply with applicable 29 CFR 1910 and 29 CFR 1926 standards. Primary fall standards include 29 CFR 1910 Subpart D; 29 CFR 1910 Subpart I; 29 CFR 1910.269(g), 29 CFR 1926 Subpart E, 29 CFR 1926 Subpart M, and ANSI Z359.

4-4.3 Non-Performance.

Ensure non-performance and remedy clauses are in maintenance contract to address non-conformance. Ensure liquidated damages address power generation revenue loss and mission impacts.

4-4.4 Warranties.

Typical wind turbine installation warranties are for two to five (2-5) years, followed by a service contract modeled on an operating life of 20 years.

Specific component warranties will vary with manufacturer. Warranties are typically limited to repair or replace, at manufacturers' discretion, the defective components, or assemblies. Warranty limits may include causes for materials, supplies, and equipment not manufactured or supplied by the manufacturer, unauthorized repairs or modifications, Acts of God, and incidental or consequential damages. If warranty does not include O&M requirements, ensure O&M contract is in place once turbine is operational.

4-4.5 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

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CHAPTER 5 DESIGN CRITERIA – BIOMASS SOLID WASTE TO ENERGY SYSTEMS

5-1 INTRODUCTION.

Solid Waste to Energy conversion is a biomass process that converts solid waste into various forms of fuel that can be used to produce thermal and electrical energy.

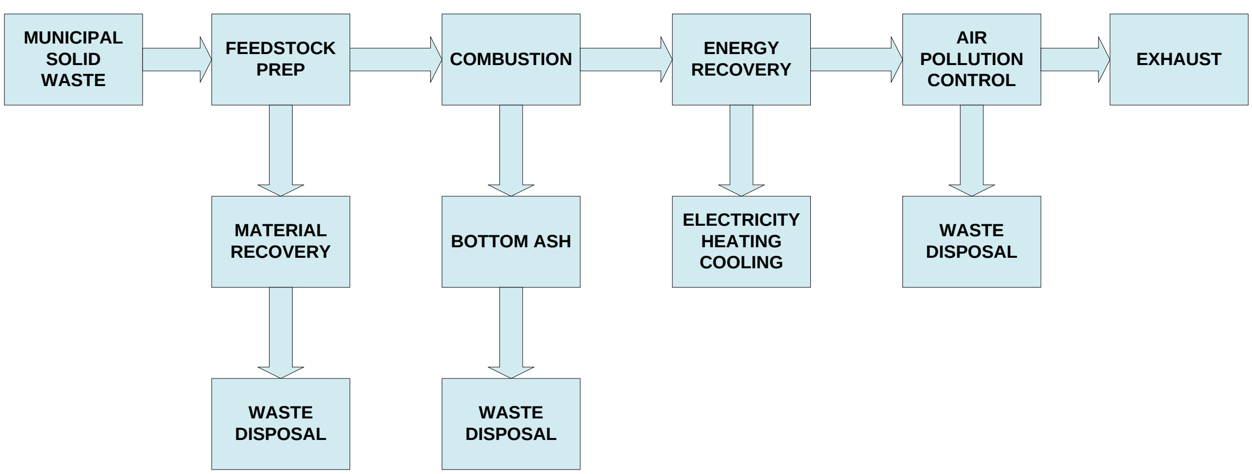
This chapter establishes the requirements for thermal conversion of solid waste to generate steam and produce electricity using combustion of municipal solid wastes in what is described as a mass burn, water wall plant.

5-1.1 Technology.

The predominant large solid waste combustors technology is the Mass Burn / Water Wall type combustor. In this type system, minimum or non-processed waste is delivered by overhead crane into the furnace through a feed hopper that uses hydraulic rams and reciprocating or roller grates.

The mass burn thermal conversion process is depicted in Figure 5-1. The mass burn plant is a direct combustion process for producing heat, electrical power, combined heat and power, or combined heat, power and cooling. The solid waste is delivered to the plant where it is prepped for feedstock by removing recyclable and hazardous materials. The feedstock is then burned with the ash being sent to waste disposal and the heat being recovered for generation of electricity, steam or high temperature hot water, and in some plants, chilled water using adsorption chiller units. The flue emissions are processed through air pollution control (APC) equipment with removal of toxic gases, acids, and particulate matter then exhausted from the plant.

Figure 5-1 Mass Burn Process of Solid Waste to Energy



5-1.2 Application.

Mass burn solid waste to energy plants require a large and continuous source of municipal waste, a large land area with access to water, sewer and natural gas, and proximity to utility transmission lines. Locate plant near large town or city industrial areas. Extensive environmental studies and permitting are required as well as extensive utility and public coordination. These plants are best suited for a municipal and utility partnering agreement using a design-build-operate contractor approach.

5-2 PLANNING.

The planning section identifies biomass technology unique planning requirements including determining the energy recovery potential, complying with environmental regulations and restrictions, and permitting.

Perform proposed and final siting coordination with OSD. 32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination with OSD is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil to avoid invalid site selections.

5-2.1 General Requirements.

Design and operate facility to cost effectively maximize power generation and district heating (if available) capacity. The fuel supply is from municipal solid waste delivered by solid waste haulers and self-haulers. 10 USC 2692 restricts the types, storage, and use of non-DoD materials, and may affect projected fuel supply. Design facility for 24 hour/365 day operation at maximum continuous rating and at maximum continuous turndown for extended time without supplemental natural gas fuel firing. Design facility life for thirty (30) years.

Provide appropriate redundancy in the chute to stack, furnace/boilers, turbine-generators, steam distribution, electrical switchgear and transformation, pollution control, and other equipment, to minimize unscheduled outages. Provide normal and emergency power systems, with the facility being self-powered during operations except in emergencies and start up conditions. Provide natural gas supplementation for boiler system start up and maintenance heating.

5-2.1.1 General Development Plan.

Prepare a general development plan for the project life cycle. Include the following phases as a minimum: feasibility, design, construction, operation, and decommissioning.

5-2.1.2 Site Planning and Development.

Use UFC 3-240-05A, Chapter 2 (for Army), and UFC 3-430-02FA, Chapter 2 (for Army/Air Force), for general site planning and development. *Note: Navy to use UFC 3-*

240-05A and UFC 3-430-02FA as reference only. Follow local shore installations planning guidance. Consider Table 5-1 during site planning evaluation:

Table 5-1 Plant Site Planning Considerations

Area	Consideration
Zoning	• Use local land use planning and zoning regulations in siting plant. • Plant should be located in a heavy industrial area, preferably close to existing power plants. • Locate plants in open areas where flue emissions are not trapped by terrain or wind patterns and the emissions are not prone to create smog. • Locate plant away from airfields and flight paths to accommodate the flue stack(s).
Economics	• Plant should be within economic range for transfer or waste truck delivery. • A properly designed and operated landfill for disposal of ash and waste residue must be within plant economic range. • Plant should be located in proximity to the waste generation area. • If supplying district heating or cooling, locate plant in economic proximity to existing district heating/cooling supply and return mains.
Infrastructure	• An adequate source of water must be available for plant operations. • Natural gas must be available for furnace starting and boiler operation in the event of a solid waste fuel interruption. • Municipal sanitary sewer should be nearby to receive the wastewater discharge polluted by waste storage liquids, slag cooling, and flue gas cleaning system. • Electrical power transmission lines and available right of ways should be nearby to connect the plant to the electrical network without high construction costs.

5-2.2 Critical Criteria.

The following criteria are critical to the municipal solid waste to energy plant planning:

5-2.2.1 Energy Recovery Potential Assessment.

Use the NREL Renewable Energy Optimization (REO) tool to model the energy generation and costs in the project defined location. Use the U.S. EPA – Research Triangle Institute (RTI) International Municipal Solid Waste Decision Support Tool (MSW-DST) (https://mswdst.rti.org/) to conduct a comprehensive energy, environmental impact, and cost model for the determining the preliminary energy recovery potential and life cycle cost analysis. Develop model based upon waste generation from residences, multi-family residences, and commercial entities.

5-2.2.2 Local Conditions / Existing Waste Management Practices.

Conduct a waste survey and forecast to establish the expected amount and composition of waste generated during the facility lifetime using the RTI MSW-DST. Assume a 30 year life cycle period.

5-2.2.3 Waste Physical and Chemical Characteristics.

Solid waste used for fuel includes Municipal Solid Waste (MSW) per 40 CFR Part 60.51b. The average lower calorific value of waste must not be less than 3,000 Btu/lb (7 MJ/kg). If actual MSW caloric value not known, use an aggregate heating value of 5,000 Btu/lb (11.6 MJ/kg) for fuel energy calculations. MSW with higher caloric values reduces the volume necessary for same unit of energy produced. Evaluate other non-MSW combustible solid waste streams as a fuel source, as permitted. Consider the following solid waste streams in planning and characterization:

- Wood pallets, clean wood, and land clearing debris;
- Packaging materials;
- Clothing materials; and
- Rugs, carpets, and floor coverings except asbestos materials.

Some solid waste, other than MSW, may be allowed in a limited segregated burn scenario, if authorized by State and Federal permits. Consider the following solid waste streams in planning and characterization:

- Waste tires;
- Construction debris;
- Waste oil and waste oil products; and
- Human and animal processed product waste (e.g. foodstuff, personal care products, pharmaceuticals, cosmetics, cleaners, detergents, waxes, etc.).

5-2.2.4 Prohibited Materials.

10 USC 2692 restricts types and use of non-DoD materials. Design and operate plant to prevent combustion of:

- Materials prohibited by State and Federal laws;
- Hazardous waste;
- Nuclear and radioactive waste;
- Explosives;
- Sewage sludge;
- Biomedical and biological waste;
- Waste containing beryllium (40 CFR Part 61, Subpart C);
- Waste containing mercury;
- Lead acid batteries;
- NiCad batteries; and
- Pressure treated wood.

5-2.2.5 Seasonal Fluctuations in Waste Quantity and Quality.

Design plant systems to account for seasonal fluctuations in waste quantities and quality.

5-2.2.6 Treatment of Rejects / Effluents.

Provide for treatment/re-use of liquid rejects / effluents from APC process wastewater, other process wastewater (boiler feed, blowdown, and bottom ash system), sanitary sewer, storm wastewater, and cooling towers. Evaluate and implement as appropriate the following best available technologies: on-site physical/chemical treatment; re-circulation of wet scrubber effluent; effluent flow buffering and storage; scrubber dioxin and furan breakthrough control; and ammonia stripping.

5-2.3 Environmental Regulation and Restrictions.

5-2.3.1 General.

Comply with UFC 1-200-01 and agency specific environmental regulations, restrictions, and specific applicable environmental guidance. In addition to Federal regulations, State and local municipality regulations may require permits, licenses, and approvals for construction and operation. Identify and compile these regulatory items and documentation requirements during the mass burn plant design, construction, and operation.

5-2.3.2 Air Quality Regulations.

A mass burn plant is subject to multiple provisions of the Clean Air Act of 1990. Comply with the two main provisions applicable to mass burn plants including Section 129 Solid Waste Combustion and Section 165 Pre-Construction Requirements. The mass burn plant will be designed to satisfy all emission requirements of 40 CFR Part 257 and 40 CFR Part 60.

5-2.3.3 Water Quality Regulations.

Design and operate the plant to ensure surface water is not polluted in accordance with the Water Pollution Act of 1956 or the Clean Water Act of 1990. Design and operate the plant to ensure ground water is not polluted in accordance with the Clean Water Act of 1972 and 40 CFR Part 257.

5-2.3.4 Solid Waste Disposal Regulations.

Limit ash emissions to not to exceed 5%, as determined by EPA Reference Method 22 per 40 CFR Part 60.

5-2.4 Interconnect Studies.

Perform interconnect studies. Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

5-2.5 Permits.

Obtain pre-construction and operating permits required to ensure facilities comply with applicable Federal, State, and local laws to ensure the facilities operators and public health and safety protection, to prevent and reduce polluting the environment, and to protect endangered species. In addition to the listed permitting activities herein, contact the state and local environmental and development offices to verify additional permitting requirements.

5-2.5.1 Environmental Impact Statement.

Perform a project Environmental Impact Statement / Environmental Assessment.

5-2.5.2 Air Permits.

Obtain State and local permitting as required under 40 CFR Part 70. For states that have not been granted full approval authority under 40 CFR Part 70, Indian country, outer continental shelf areas, and other areas/authorities not covered by 40 CFR Part 70, permitting is required under 40 CFR Part 71.

5-2.5.3 Wastewater Discharge Permits.

Waste Water or Stormwater Permit. Obtain a National Pollutant Discharge Elimination System (NPDES) permit in accordance with the Clean Water Act.

Solid Waste Disposal Permit. Regularly sample and test the mass burn solid waste ash and other residues in accordance with permit requirements to determine if ash is hazardous waste. Hazardous material and hazardous waste ash must be disposed of as hazardous waste in accordance with the Resource Conservation and Recovery Act (RCRA) and 40 CFR Parts 266-273.

5-2.5.4 Dredge and Fill Permit.

Structures or work affecting the course, condition, location, or capacity of navigable waterways or wetlands requires a Department of the Army Permit from the United States Army Corps of Engineers (USACE).

5-2.5.5 Haze and Visibility / Prevention of Significant Deterioration (PSD).

Consultation and agreement with U.S. Department of Interior - National Park Service and USFWS, and U.S. Department of Agriculture - National Forest Service Federal Land Manager(s) is required if plant is located within 185 mi (300 km) of a Class I area in accordance with 40 CFR Part 81.

5-2.5.6 Incidental Take Statement / Permits.

Obtain permits and authorizations required under the Endangered Species Act of 1973 for activities that may “take” (kill) native threatened or endangered species. Contact the nearest USFWS Ecological Services Office and determine if the proposed project is likely to result in a take, whether a permit is required or if other options require consideration. Obtain an Incidental Take Permit in accordance with 50 CFR Part 13 and 50 CFR Part 17.

5-2.5.7 FAA Permit.

Comply with 14 CFR Part 77 and file a Notice of Proposed Construction or Alteration with FAA.

5-2.5.8 Other State and Local Permits.

Contact State and local environmental, development, and transportation offices for construction and operating permits for the following:

- Boiler / pressure vessel;
- Elevator and kindred equipment;
- Oversize/overweight vehicles;
- Highway construction;
- Land use; and
- Historic sites review.

5-2.5.9 Permits.

Coordinate and obtain utility permits for water, sanitary sewer, fuel gas, and electric utilities.

5-2.6 Cost Estimation / Analysis.

Use the MSW-DST to provide a screening level cost and a report of environment aspects for the proposed waste to energy plant.

5-2.6.1 Capital Costs.

Use capital cost data from the U.S. Energy Information Administration for initial capital cost estimates. Capital costs to include the total investment costs for equipment, construction, and engineering, for the plant, electrical grid connection, roads, utilities, and new infrastructure to support the plant.

5-2.6.2 Operation and Maintenance Costs.

For initial planning, calculate fixed O&M and variable O&M costs using O&M cost data from the U.S. Energy Information Administration.

5-2.6.3 Sale of Energy.

Include the sale of energy from the plant in the economic analysis. The income includes the sale of electricity and, where district heating is available, can include the sale of steam or high temperature hot water.

5-2.6.4 Sale of Materials Recovery.

Include in the economic analysis the potential value of selling recovered materials. As a minimum, include ferrous and alumina recovery.

5-2.7 Coordination.

Establish an institutional framework consisting of the four major project stakeholders of government authorities, waste sector companies, community groups, and energy sector companies. Review with the stakeholders the financial, environmental, and waste flow issues. Perform a comprehensive stakeholder analysis for both the existing waste disposal and future waste to energy plant. Establish agreements that resolve issues before the plans are made to build the plant.

5-3 DESIGN CRITERIA.

5-3.1 General Buildings.

Administrative, maintenance, operations, security, and other similar facilities of the plant must comply with UFC 1-200-01. Refer to UFC 3-240-05A (for Army) for additional facility requirements. For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance.

5-3.2 Mass Burn Plant.

5-3.2.1 Functional Design of Plant.

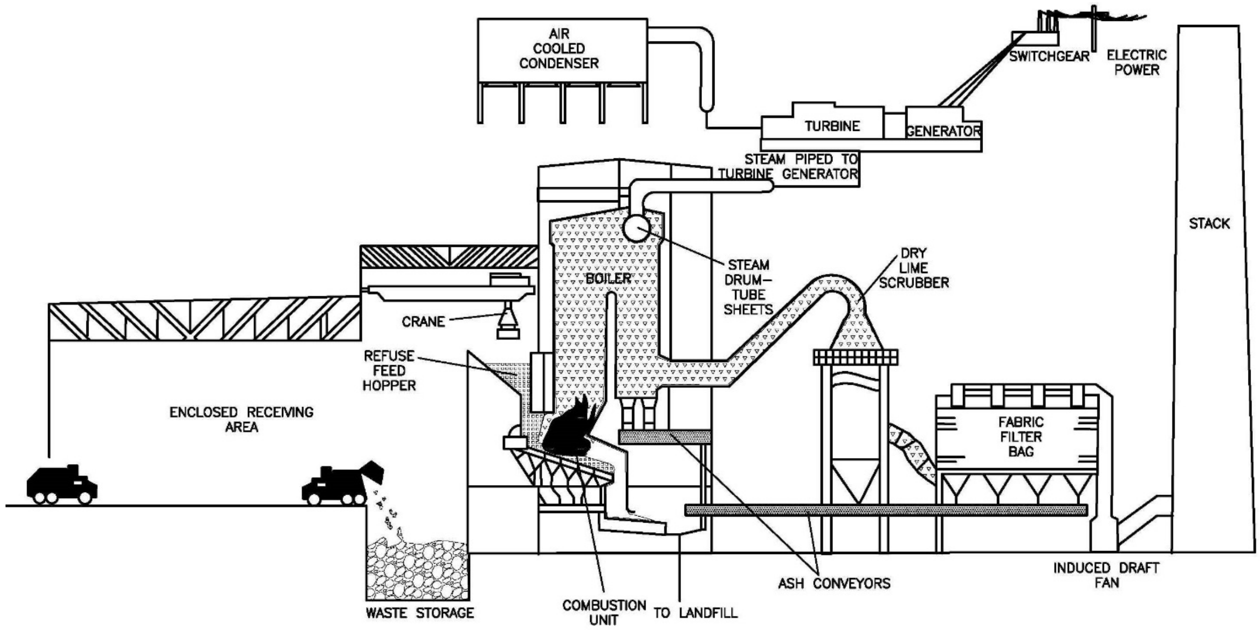
The Mass Burn Plant primary functions are to include: 1) receive the solid waste; 2) process and store the waste; 3) convert the solid waste to energy; 4) distribute the energy from the solid waste conversion; and 5) energy conversion process waste by-products disposal. To accomplish this, provide the following main systems: refuse receiving, handling and storage system; combustion and steam generation system; flue gas system (APC equipment); power generation system; steam condenser and make up water systems; residual waste disposal system; and supporting systems.

5-3.2.2 Process Flow and Layout.

Use the Figure 5-1 process flow as a guide to developing the plant layout. Figure 5-2 presents a typical plant layout. The waste to energy plant receives MSW on the tipping floor where it is prepped for feedstock. Large, bulky, and hazardous items are removed from the waste. In some operations, metals are removed and waste reduced to an optimum burning size. MSW moves from the storage pit to the boiler feed hopper for combustion. The feed hopper places MSW onto a grate using control gates and hydraulic rams to push the waste on to a grate in the furnace where it is dried out and combusted on the grate. Ash is discharged through the grate bottom into a water filled quench pit, and then transferred by a conveyor to an ash load out area for disposal in a landfill.

Energy recovery from the combustion process is transferred by water from the boiler walls and from the flue gas off the boiler. The heat absorbed creates steam that is used to operate a steam turbine. The steam from the turbine is condensed through a cooling tower and re-cycled through the boiler. The turbine is connected to a synchronous generator that rotates and produces electricity. In many applications, the heat is also transferred to district heating through steam or high temperature hot water systems. In some applications, the heat is converted to chilled water using absorption chiller units. The flue emissions are processed through APC equipment including spray dryers for acid gas, activated carbon injection for mercury control, ammonia for NOx control, and a baghouse for fly ash. The flue gas is then released through the plant flue stack.

Figure 5-2 Solid Waste to Energy Mass Burn Plant



5-3.2.3 Specific Building Requirements.

Provide the following solid waste to energy plant facilities:

- Gatehouse / scales;
- Tipping floor / waste sorting;
- Waste storage pit;
- Boiler building;
- Spray dryer;
- Baghouse;
- Waste material storage facility;
- Turbine-generator building;
- Cooling towers;
- Switchgear facility;
- Utility substation;
- Black start generator plant;
- Continuous Emission Monitoring System (CEMS) facility;
- Fire pump house;
- Administration;

- Maintenance; and
- Security guardhouse.

5-3.2.4 Layout.

Design facility with the concept of providing efficient operations and maintenance activities throughout the facility life. The design process must include a general configuration of all proposed buildings and structures, roads, parking and paved areas, as well as drainage features and any associated retention basins.

Design the facility roadway system to provide a traffic pattern allowing simultaneous traffic to both enter and exit the facility, and allow unencumbered travel of vehicles in both directions throughout the facility.

5-3.2.5 Materials.

Select all materials used for durability and longevity.

- Facility structure: concrete or steel construction.
- Exterior wall surfaces: steel with factory finished coating system or architectural masonry.
- Roofing: metal, sloped for drainage.
- Exterior personnel doors: painted galvanized insulated core steel with window lights where appropriate.
- Overhead doors: painted galvanized steel.
- Windows: insulated double pane glass with insulated aluminum jambs.
- Floors: select finishes based upon safety and use.
- Open grate working platforms, open grate stairs, ladders, ladder cages, and handrails: use steel with galvanized coated after fabrication. Where exposed to corrosive materials, coat steel with a suitable coating system resistant to the specific corrosive materials.

5-3.3 Refuse Receiving, Handling and Storage System.

The refuse receiving, handling and storage system includes the refuse receiving area, tipping floor, waste storage, and overhead grappling cranes.

5-3.3.1 Refuse Receiving Area.

The refuse receiving area accommodates the business operation for logging, weighing and receiving waste from commercial waste haulers and self-haulers (residential customers). Design the receiving area for:

- Weighing all vehicles entering and leaving;

- Eliminating waste transfer trailers and trucks backing up needs, except at the tipping floor;
- Allowing only commercial waste haulers to enter the tipping floor;
- Providing separate area for residential customers to unload into a container area with the containers shuttled to the tipping floor by the plant personnel;
- Locating site refuse receiving area facilities to eliminate or minimize: intersections; backing up; sharp turns or U-turns; and
- Adequate off-street queuing during peak operating times.

Design on-site traffic control in accordance with the Federal Highway Administration Manual of Uniform Traffic Control Devices requirements. Provide a truck helper shelter before the scales so that only the truck driver is permitted to enter the tipping floor to maximize safety by minimizing the number of personnel in the facility. Provide heating and cooling of truck helper shelter and include single toilet room with lavatory and water closet. Provide area lighting in accordance with UFC 3-530-01. Provide area lighting for all process equipment that may require maintenance after dark. Numerous states have siting and design requirements for waste transfer operations. Consult these requirements for the state where the plant is being located.

5-3.3.2 Scale House.

The scale house is located after the entry gate and usually set back sufficiently from the gate to ensure off-road queuing. Provide:

- A scale house building with number of scales sized for the daily and hourly arrival patterns of waste delivery;
- Capability for adding additional future scale(s) for growth;
- Inbound and outbound truck scales with unattended self-service terminal and remote weight display (aboveground pit-less, full truck, concrete deck type with weighbridge supported by the load cells);
- Truck scales (in the United States and North America) compliant with United States National Institute of Standards and Technology (NIST) Handbook 44 requirements and carry the National Type Evaluation Program (NTEP) Certification issued by the National Conference on Weights and Measures;
- Truck scales (in other areas) that meet the local government or the International Organization of Legal Metrology requirements, as appropriate;
- Walk up deck adjacent to aboveground scales, receiving windows and doors on inbound and outbound sides, trucker lobby with customer window, business area, employee toilet room, employee break area,

storage area, IT and scale equipment closet, and separate truck helper shelter;

- Inbound and outbound automated gates; and
- Telecommunications equipment.

Provide two radiation detectors at the scale house to monitor for radioactive materials. Detectors are to alarm at the scale house, security guardhouse, administration building, and central control room. Provide a paved area, at safe distance from occupied structures, to allow vehicles with detected radioactive material to park until State authorities are notified and can verify concentration levels.

5-3.3.3 Tipping Floor.

Use the following requirements in the tipping floor design:

- Provide metal building with partial reinforced concrete walls;
- Reinforce concrete tipping floor walls to a minimum height of 5 ft. (1.5 m);
- Construct walls and floors subject to damage through repeated impacts with 6000 psi (41 MPa) reinforced concrete;
- Provide truck receiving area to accommodate multiple waste trucks without stacking;
- Provide truck doors with minimum opening of 20 ft. wide by 20 ft. high (6 m x 6 m);
- Provide protective bollards inside and outside truck doors;
- Totally enclose the tipping floor and sized for a minimum of 130 sq. ft. (12 sq. m) for each ton-per-day incinerator capacity per UFC 3-240-05A (for Army). For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance;
- Size tipping floor area for peak container unloading and for tractor trailer size load of solid waste delivery;
- Size tipping floor for tractor trailer turn radius with minimum width of 150 ft. (46 m);
- Provide tipping floors to accommodate vehicles with maximum of 75 ft. (23 m) length and maximum legal weight limit of 80,000 lbs. (36,000 kg) gross, single axle of 20,000 lbs. (9,100 kg), tandem axle of 34,000 lbs. (15,400 kg), triple axel of 42,000 lbs. (19,000 kg), and quad axle of 50,000 lbs. (22,700 kg);
- Provide tipping floor with an additional 3 in (7.6 cm) concrete wear layer;
- Provide embedded galvanized steel protection on outside corners and edges subject to damage from trucks and grappling cranes; and

- Provide vehicle stops in front of each pit with spacing for drainage and broom cleaning of tipping floor into pit.

5-3.3.4 Sorting and Contaminant Removal.

Hand picking, hazardous material removal, and size reduction are required processes to render the waste easier to handle and make particles the size required by the furnace. Provide hand picking area with tables, hoppers and sorting belts, at tipping floor to remove large items (i.e. appliances, refrigerators, and equipment), batteries, and other specified hazardous materials. Size reduction can be single or multi-stage depending upon the furnace size and combustion requirements. Evaluate guillotine hydraulic shears and shredders for reducing oversized material for combustion based upon oversized material volume, explosion risk, and economic analysis. Provide size reduction equipment based upon the analysis. Provide guillotine-type hydraulic shears for reducing oversized items. Provide adequate access, lighting, overhead hoists, and welding equipment receptacles for equipment maintenance.

Evaluate throughput, availability, and redundancy for the material recovery and contaminant removal system. Include environmental control equipment for dust collection, noise suppression, odor control, explosion control, and HVAC. Refer to UFC 3-240-05A (for Army) for waste processing and bypass requirements. For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance.

5-3.3.5 Ferrous Recovery.

For ferrous metals, use multi-stage magnetic separators to achieve a minimum recovery yield of 85% consisting of magnetic belts, mixed waste conveyor, ferrous waste conveyors, and non-ferrous collection conveyor. Provide conveyor to transfer to ferrous bulk storage.

5-3.3.6 Aluminum Recovery.

Use eddy current separators to eject aluminum material from the moving waste stream. Provide a can flattener for ejected waste. Provide a conveyor to transfer to aluminum bulk storage.

5-3.3.7 Waste Storage.

Provide a waste storage building sized for a minimum five (5) day capacity at facility's maximum continuous rating to facilitate major equipment repairs. Site the waste storage building adjacent to the boiler building.

5-3.3.8 Pit Storage.

Design the waste storage pit for a minimum five (5) day capacity based upon a bulk density of 500 lb/yd^3 (300 kg/m^3). The pit storage volume will be based upon the pit volume up to the tipping floor and the volume above the tipping floor assuming the waste above the tipping floor is stacked at a 45 degree angle from the charging floor wall to the tippling floor. The pit storage capacity will include 2/3 below the tipping floor and 1/3 above the tipping floor as geotechnical conditions allow. The pit depth should be 30 to 45 ft. (9-14 m) below grade, if possible, as groundwater conditions allow. The number and arrangement of bays for refuse truck unloading will be based on the peak container flow.

Include the following storage pit components/requirements:

- Construct using 6000 psi (41 MPa) reinforced concrete, minimum;
- Slope storage pit floor to perimeter sump;
- Totally enclose storage pit under negative pressure using the boiler combustion air system;
- Provide dust control spray system;
- Provide rodent and bird controls; and
- Include fire canons controlled from the pit operator control station and standpipe systems at tipping floor and charging floor.

5-3.3.9 Refuse Handling Crane.

Provide a minimum of two (2) refuse handling cranes. Select cranes rated for MH CMAA 70 Class F (continuous severe service) in accordance with UFC 3-240-05A (for Army). For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance. Cranes are to be overhead bridge, non-riding, type meeting the requirements of ASME B30.2. Specify cranes for continuous operation configured to manage refuse in the receiving and storage facility as well as to feed refuse to the charge hoppers to the boilers and capable of operating with a full load at minimum speeds. Cranes must be capable of weighing each bucket or grab load prior to discharge into feed chute. Provide separate motors for the hoist bridge, trolley drive, and grapple. Use interchangeable orange peel type grapples. Size the grapple based upon duty cycle quantity analysis of material being moved from the pit to the furnaces, the distance to move the material, crane speeds, and time required for mixing and stacking material in the pit.

Design the crane operator control station (or pulpit) to accommodate a minimum of two operators and control consoles, and allow operation of both cranes simultaneously. Design the control station to provide full view of the storage pit and charging hoppers. Provide control station with independent heating, ventilation and air conditioning system at positive air pressure relative to the pit and tipping floor. Provide control station with CCTV to monitor charging hopper level and incoming waste delivery at the tipping floor. The cranes will be equipped with semi-automatic operation features to minimize operator stress.

5-3.4 Combustion and Steam Generation System (Boiler).

5-3.4.1 Feed System.

The charging hopper discharges the solid waste into the delivery chute. Provide a top loading charging hopper for each combustion train. Design charging hoppers to be large enough to prevent spillage on the charging floor and with slopes steep enough to prevent solid waste bridging. Provide hydraulically actuated gate between the charging hopper and upper chute. Gate to automatically close in the event of a power failure.

Design the waste chute feeding the refuse stokers for sufficient height to provide an air seal to the furnace stokers. Design chutes with dimensions and contour for self-relieving to avoid bridging, but not less than 4 ft. (120 cm) wide and the furnace width. Provide means of access to reposition or remove particles in the chute and to assist in firefighting. Provide charging throat with water cooling and refractory lining. Include chute refuse level sensor to alarm crane operator and control room, and include hydraulic shutoff grate to prevent back burn during shutdown.

5-3.4.2 Refuse Stokers and Grates.

Design stokers and grates for burning solid waste, to avoid excessive refuse turning, and to even incoming waste distribution. Use a minimum of three grate sections, including drying grate, burning grate, and finishing grate. Bottom ash is discharged from the finishing grate into a water quench pit, and from there, it is transported by conveyor to the ash storage facility. Locate grates mechanisms outside the furnace. The grates are typically air cooled independent of primary air. If high calorific waste is used, water cool the grates. Feed waste refuse onto the grate with a charging ram. Charging rams will be hydraulic type with at least one hydraulic cylinder for each longitudinal grate section.

Provide a complete hydraulic system for each boiler system for operation of grates, charging rams, feed chute, and ash recovery. Include a fully automatic, forced, central lubrication system for lubricating the stoker with pumps and alarm system.

5-3.4.3 Auxiliary Fuel Burners.

Provide auxiliary fuel burners for use during start-up and shut down with total capacity of not less than 40% of the boiler’s maximum continuous rating. Burners are water cooled, natural gas type with low NOx emission. Design burner in accordance with NFPA codes.

5-3.4.4 Ash Quench Pit.

Ash quench pits are water filled troughs with submerged chain driven mechanical conveyors powered by hydraulic motors. Provide double chamber troughs formed from a single piece of steel. Provide with abrasion resistant side wear liners and plate separators. Provide dewatering ramp and chute for disposal of ash into concrete bunker. Extend boiler seal plates directly into the water in the upper trough or provide transition hopper. Seal plate pinch point minimum clearance is 4 ft. (120 cm). Include roll out wheels to allow the entire system to move on rails to the side to allow boiler shutdown maintenance.

5-3.4.5 Combustion Air.

Use 100% excess air to burn municipal solid waste. Pull all combustion air from the refuse storage and reception building to minimize dust and odor. Provide primary combustion air beneath the grate with adjustable zoning. Inject secondary combustion air at high velocity above the grate through ports spaced equally around the grate's perimeter. Regulate primary and secondary combustion air flow against feed rate, type of waste temperature, and oxygen levels using computer controls.

Provide a minimum of one underfire fan with pre-heat, one overfire fan, one induced draft fan, and one secondary air fan for each boiler with air ducts. Provide 20% to 40% of total air as overfire air and 60% to 80% as under fire air to allow a total maximum air flow of 120%. Size fans for combustion air requirements and ambient conditions. Locate induced draft fan after APC equipment. Pre-heat under-fire air with steam heating coil located between the underfire fan and air plenums. Size coils for worst-case ambient conditions and provide freeze protection. Fit air duct systems with non-plugging type flow measuring device with a transmitter for remote read out and use in combustion rate control systems. Provide ducts with straight sections or flow straighteners upstream and downstream of the flow measuring device to assure the measuring device's accuracy.

5-3.4.6 Ash Load Out.

Discharge moist ash from ash quench pits by conveyor system and transport to the storage area using an ash conveying system. Design the complete ash conveying system to consist of both a primary and secondary conveyor to transport furnace bottom ash, grate siftings, fly ash and APC fly ash to a centralized location. Provide two (2) 100% capacity ash conveyors to remove bottom ash from the boilers and convey the bottom ash and fly ash to the ash load out area, for maximum combustion units' availability. Provide two (2) 100% capacity conveyors to transfer APC fly ash from the APC fly ash collection equipment to the storage area. Include provisions for combining the APC fly ash with bypassed bottom ash in the event that the metals recovery system is not operational. Design the ash conveying system for a minimum of 100 lb/ft^3 (1602 kg/m^3).

5-3.4.7 Interior Equipment.

Place interior equipment (the grizzly scalper, ferrous and non-ferrous metal separating equipment, and fly ash conditioning equipment) and support steel at grade elevation on six (6) in (15 cm) minimum concrete housekeeping pads. Design the structural steel above the ferrous recovery system for hoisting equipment as required for optimizing system performance and maintenance. Protect all exterior walls that come in contact with ash laden water, such as the area around the inclined ash conveyor entrance and walls adjacent to the ferrous recovery equipment, with fiberglass panels or other corrosion resistant materials. Provide translucent panels for lighting during daylight hours to minimize energy use.

5-3.4.8 Waste Material Storage.

Design the waste material storage building for processing and storing ash load out, ferrous and non-ferrous metals, and oversized materials. Include a grizzly scalper and the inclined conveyor in the footprint of this structure. Provide wheel wash system for ash and metal handling trucks prior to exiting the structure. Accommodate a minimum of five (5) days storage for processing, separating, and storage of non-ferrous and ferrous metals in the ash load out area. Protect all interior panels, purlins, grits, steel structures, and equipment against high pH ashes, high humidity, and a hot atmosphere. Apply a protective coating to structural components and non-metallic building siding. Enclose the area within a concrete structure with cladding to ensure dust suppression. Design the ash concrete bunker as a water retaining structure, with draining slopes at the bottom of the trench to a sump.

Route wastewater from the waste material storage building drains to a settling basin located immediately outside of the building. Include removable covers to prevent rainwater from entering the settling basin system. Position the sump such that water may drain from the ash bunkers into the sump by means of sleeves located at the building wall base. Gravity drain collected sump wastewater through a minimum of 24 in (61 cm) wide floor trenches fitted with removable diamond plating and route wastewater to the settling basin.

5-3.4.9 Material Recovery.

Design the ferrous recovery, associated conveying and storage area to achieve a throughput rate of 150% of projected recovery tonnage per day. Provide a ferrous recovery system with a minimum collection rate of 80% of magnetic ferrous materials within the ash waste over one (1) in (2.5 cm) in diameter including ferrous metal removed by the grizzly scalper. The ferrous metals recovery system is located at the discharge end of the quenched bottom ash conveyors in the Ash Load Out building. Provide a separate storage area for ferrous materials inside the Ash Load Out building. Provide roll-off containers or other suitable vehicle for transport for recovered ferrous material loaded the storage areas. Design the separation and recovery system with at least one magnet, one vibratory feeder screen, and necessary chute work and product distribution conveyors. Provide transfer conveyors as required to transport ferrous metals and remaining ash residue to separate storage bunkers or containers. Include ample space and access for maintenance of all system components. Design the system to minimize residual ash being carried with the recovered metal.

Design the non-ferrous recovery, associated conveying and storage area to achieve a throughput rate of 150% of projected recovery tonnage per day. Provide a non-ferrous recovery system with a minimum collection rate of 60% of non-ferrous materials greater than 5/8 in (1.6 cm). Recovery to occur upon completion of recovery of ferrous materials from the ash. Use eddy-current separators in order to minimize possible damage from errant ferrous material. Provide a separate storage areas for non-ferrous metal inside the Ash Load Out building. Recovered non-ferrous material is then loaded from its storage bunker into roll-off containers or other suitable vehicle for transport. Provide transfer conveyors as required to transport non-ferrous metals and remaining ash residue to separate storage bunkers or containers. Include ample space and access for maintenance of all system components.

5-3.4.10 Waste Heat Recovery / Steam Generation System.

Provide single drum, multiple pass water tube type with integral welded membrane waterwall cooled furnace, superheater and economizer steam generating equipment. Directly couple each boiler to its respective refuse combustion stoker.

Design each combustion train to be automatically controlled when in operation and control of each combustion train is independent of the others. Provide manual controls to select desired steam flow. Ensure control system maintains all process conditions within safe limits and that emissions, including NOx, $S0_2$, HCl, dioxin and furnace concentrations, are within specified limits of the environmental permits.

5-3.4.11 Heat Transfer Cleaning System.

Determine cleaning frequency by the fouling problem severity. Perform trade off analysis of cleaning process while the plant remains in operation (on-line cleaning) and for when plant is shut down the (off-line cleaning). Implement the best approach comparing operational, technical, and cost factors.

Steam soot blowers, mechanical rappers, or combination of methods may be utilized in conjunction with on-line water washing, if needed, to meet on-line operating requirements and downtime limitations as well as environmental guarantees. Space and arrange tubes to minimize erosion, slagging, and fouling and to promote effective cleaning of tube surfaces with soot blowers or a rapper system.

5-3.5 Flue Gas System.

5-3.5.1 Air Pollution and Control Equipment.

Use UFC 3-430-03 for identification of air pollution emission rates and selection of control equipment required to meet, local, State and Federal compliance levels.

5-3.5.2 Air Quality Control Requirements.

Ensure APC equipment has capability to meet U.S. EPA and State requirements for control of NOx, dioxin, mercury, acid gas, and particulate removal. Provide separate APC systems for each combustion train in the plan. Dump stacks that release any untreated flue gases are not allowed.

Select air pollution and control equipment by using EPA Best Available Control Technology (BACT) Analysis. BACT air pollution emissions are limited based upon the maximum degree of reduction for each type of regulated pollutant achievable through processes and systems available. BACT is determined by State permitting agencies on a case-by-case basis considering energy, environmental, economic, and other costs in its determination. BACT cannot be less stringent than the Federal New Source Performance Standards (NSPS), but it can be more. BACT requires that emissions of any pollutant not exceed the standards under 40 CFR Part 60 and 40 CFR Part 61.

5-3.5.3 NOx Control.

Use one of two the different methods for control of NOx used in North America: Selective Catalytic Reduction (SCR) or Selective Non-catalyst Reduction (SNCR). Perform operational trade off and life cycle cost analysis and determine the best approach to meet NOx control objectives.

5-3.5.4 Activated Carbon Injection (ACI) System – Mercury/ Volatile Organics Control.

ACI is currently designated as the BACT by the EPA to control the release of trace organics including dioxins, furans, and mercury into the atmosphere by adsorbing these chemicals onto its surface. Use powered activated carbon (PAC) injection. One ACI system will be provided for each boiler/furnace system. Include redundancy of spare blowers and feeders to assure reliable operation. Injection will be between the spray dryer and the baghouse.

For the ACI System, include the following:

- Storage silo for minimum seven (7) day storage;
- Feed hopper;
- Truck unloading station;
- Blowers to provide motive air for transporting PAC to the injection points;
- Feeder;
- Controls to include truck unloading control, radar level sensing, and bin vent filter pressure differential; and
- Personnel safety equipment.

5-3.5.5 Acid Gas Scrubber.

Provide acid gas scrubbers to control acid gas emissions of HCl, SO_2, and HF. There are numerous technologies for acid gas removal including wet scrubbing, semi-wet scrubbing, and dry scrubbing. Provide dedicated acid gas spray drying scrubber for each combustion train using spray drying method. Design the scrubber so that the flue gas exiting the spray dry scrubber is kept above the acid dew point temperature.

For the Acid Gas Scrubber system, include the following:

- Spray drying scrubber (also known as spray dryer adsorber) of lime slurry reagent to meet Subpart E. b. emission standards for SO_2 and HCl and the BACT Emission limit for sulfuric acid mist and fluorides;
- Truck unloading station;
- A minimum of two lime/hydrated lime storage silos;
- Two lime slurry preparation systems;
- Spray dryer absorber vessel, atomizers, product removal system, and support equipment;
- Instrumentation and controls; and
- Personnel safety equipment.

5-3.5.6 Fabric Filter System (Baghouse).

Provide fabric filter system. Use reverse air or pulse jet type cleaning baghouse with multi-compartments to facilitate cleaning and maintenance. Provide a filter bag leak detection system that is capable of continuously monitoring relative particulate emissions (dust) loadings in the baghouse exhaust in order to detect bag leaks and other upset conditions. Include hoppers to store collected ash discharged from the baghouse filters during the cleaning process. Provide instrumentation and controls for the baghouse to include air pressure monitoring, cleaning cycle control, hopper level alarms, hopper heater control, differential pressure measurement, fan motor current, and inlet gas temperature measurement.

Provide inspection access at the following points:

- Stack exit;
- Filter clean side;
- Bags, cages and bag attachments;
- Cleaning mechanisms and equipment;
- Stack pressure gauges;
- Solid discharge valves; and
- Hoppers.

5-3.5.7 Flue Stack.

Design and construct flue stack in accordance with ASCE/SEI 7 and NFPA 211. Base flue stack height upon pollutant dispersion analysis and FAA requirements. Design stack for all environmental and seismic conditions which it may be subjected.

Construct flues of steel with circular cross section. Provide an insulated, self-ventilating flue liner to limit heat loss of flue gas to not more than ten (10) ^{o}F (-12 ^{o}C) after exiting the NOx reduction system. Include access platforms, safety railings and ladders will be provided to access inspection, test and cleanout ports, obstruction lighting, and lightning protection system in accordance with Occupational Safety and Health Acto (OSHA) requirements. Provide obstruction marking and lighting for aviation safety in accordance with FAA AC 70/7460-1K.

5-3.6 Power Generation System.

Use condensing turbine-generators in a packaged configuration, complete with condenser, sized for steam. Rate boilers at the maximum combustion rate (MCR).

5-3.6.1 System Design.

Ensure the power generation system design includes the turbine, generator, oil system, hydraulic system, backup power, and operating controls.

5-3.6.2 Operating Conditions.

Ensure the turbine – generator operates over the broad range of combined heating plant system utility load and temperature requirements, if used.

5-3.6.3 Turbine.

Provide steam turbines that conform with ISO 14661 *g*eneral requirements. Where using cogeneration system that simultaneously supplies power, and heating or cooling, conform to ISO 26382:2010*.* Select the best steam turbine classification based upon economic analysis in accordance with DoD Instruction 7041.3. Use present value analysis and include the following cost elements:

- Capital costs; and
- Operating and maintenance costs (include equipment operating efficiencies).

Design turbine(s) as a complete package system mounted on bases for quick installation and alignment verification with steam extraction points at different pressures corresponding to different system temperatures based upon economic analysis. Design turbine to operate at a constant speed. Combine high pressure and intermediate pressure sections into a single casing to provide a compact system minimizing plant floor space. Low pressure section(s) are typically housed in a separate casing if not a single stage turbine. Provide DC backup power for critical lubrication systems.

5-3.6.4 Generator.

Provide a totally enclosed, air or hydrogen cooled, synchronous generator sized for continuous operation and directly connected to steam turbine. Use air cooling for generators up to 60 MW in capacity. Use hydrogen cooling for generators for over 60 MW in capacity. Provide on-site hydrogen generation system for hydrogen cooled generators.

Provide turning gear to thermally stabilize generators for a period of 24 hours or until the generator is cooled below 212 ^{o}F (100 ^{o}C), whichever is greater. The turning gear will start when the turbine speed drops to 100 rpm, then engage and rotate the turbine at a speed of 30 rpm to ensure an oil film is maintained in the journal bearings and to create turbulence in the cylinder to cool the cylinder and shaft uniformly.

5-3.7 Steam Condenser System.

5-3.7.1 Steam Dump.

Provide a steam dump capable of handling the following events: 1) turbine over-current protection device trip; 2) turbine failure; 3) continued furnace solid waste process at MCR regardless of turbine outage; or 4) other system failure. The steam dump will release steam until the plant can achieve an orderly shutdown or turbine operation can be restored.

5-3.7.2 Cooling Tower.

Design the condenser cooling tower in accordance with the weather data requirements of UFC 3-400-02 and NFPA 214. Size cooling towers to meet the turbine condenser(s) and other plant cooling loads requirements. Account for prevailing winds, proximity to existing or proposed transmission lines and facilities, and the boiler stack when siting cooling towers.

Provide cooling towers with fiberglass or concrete frame and film filled as appropriate for maximum wind conditions. Partition tower cells such that each cell can be operated independently of remaining cells. Conduct an on-site thermal performance test in accordance with the CTI ATC-105 standards to ensure installed tower(s) meet thermal performance requirements. Use high efficiency fill and drift eliminators. Size cooling towers to have a minimum 10 ^{o}F design approach between the cooling water outlet and the ambient wet bulb temperature at the design wet bulb temperature.

5-3.7.3 Circulating Pumps.

Provide separate primary and alternate circulating pumps for the turbine condenser(s) and separate primary and alternate water pumps for the other plant cooling loads.

5-3.7.4 Chemical Feed System.

Provide complete chemical feed system for cooling system circulating water to protect against corrosion and bio-growth.

5-3.7.5 Air Removal Equipment.

Provide air removal equipment for each condenser.

5-3.7.6 Surface Condenser.

Design condenser in accordance with Heat Exchange Institute (HEI) allowable stresses for tubes per ASME, and bypass headers in accordance with EPRI standards and codes. Provide a surface condenser with shell and tube exchanger. Equip the condenser with a minimum of two tube passes and divided water box. Provide an ejector assembly, atmospheric relief valve, and limit the inlet velocity to header to 200 to 300 feet per second (fps) (60 – 90 m/s). Extend the bypass headers are to extend along the entire tubes length and equip with the smallest diameter orifice. Provide impingement protection for tubes to also include dummy tubes.

5-3.7.7 Dump or Bypass Condenser.

Provide a dump or bypass condenser and use in conjunction with the surface condenser during periods of startup, shutdown, and turbine generator unavailability.

5-3.7.8 Condenser Hotwells.

Size the hotwell to contain all condensate produced in the condenser in a period of one minute under conditions of design load in accordance with HEI Standards for Steam Surface Condensers. Employ hotwell level controls with three level transmitters to maintain a normal level in the condenser hotwell. Controls will be dual redundant.

5-3.7.9 Blowdown Control and Treatment.

Provide automatic modulating blowdown control to maintain dissolved solids in accordance with recommended practices of ASME Consensus on Operating Practices for the Control of Feedwater and Boiler Water Quality in Modern Industrial Boilers. If economically justified, employ a boiler blowdown heat recovery system using a flash tank and heat exchanger.

5-3.7.10 Boiler Feed Pumps.

Provide one boiler feed pump per boiler. Size the pump for 125% of boiler steam capacity.

5-3.7.11 Feedwater Control System.

Provide a minimum of two (2) high pressure boiler feedwater pumps providing 200% of total design. Design the feedwater system to achieve the maximum flexibility for operations ranging from 33% MCR to peak facility operation. Utilize a boiler feed pump system driven by an electric motor, steam turbine drive, or combination of the two with an option for variable speed drive for the electric motor. The feedwater pump arrangement must be capable of providing the feedwater flow required for full capacity plant operation as well as providing partial flow to individual boilers if one or more boilers are shut down. The design must assure adequate NPSH is available to the boiler feed pumps during transient load conditions, including turbine trip at full load.

Rate pumps capacities to meet ASME code when pressure relief valves are open on high drum pressure.

Provide a three-element feedwater control system to include at a minimum: drum level transmitter, steam flow transmitter, feedwater flow transmitter, drum level controller, manual/automatic control station, feedwater control valve, steam flow element and feedwater flow element.

5-3.7.12 Condensate Pumps and Circulating Pumps.

Provide two motor driven, variable speed condensate pumps per boiler. Size each pump for 125% of boiler steam capacity. Provide bypass orifice at each pump.

Provide a minimum of two (2) circulating water pumps for condensing heat exchanger arrangement, each with a capacity equal to either unit MCR or facility MCR, as appropriate.

5-3.7.13 Miscellaneous Pumps.

Provide miscellaneous pumps and accessories as required by the final facility design. Provide 100% redundancy for all pumps. Include motors, couplings, coupling guards and baseplates for all pumps as applicable. Provide all special tools required for maintenance and installation of applicable pumps. Pump capacities to include a minimum of 10% margin, and a 20% margin for head, for all pumps, based on the final piping arrangement. Design pumps, as a minimum, in accordance with the manufacturer's standard for the service intended.

Perform a failure mode and effects analysis for the various pump categories as required. Additionally, provide a hierarchy according to which pump functions are grouped based on critical safety needs. Provide this during the design review. The results of this analysis shall indicate which functions require redundant pumps, priority circuitry, and back-up power supplies.

5-3.8 Water Supply, Makeup and Treatment.

5-3.8.1 Design.

Design domestic water supply, and makeup and treatment systems in accordance with UFC 3-401-01 and UFC 3-420-01*.*

5-3.8.2 Domestic Water Supply.

Obtain all facility domestic water (potable water) by connecting to the local utility supplier or through an on-site water well that is permitted, designed, and installed in accordance with local, State and Federal requirements. Provide all piping, valves, chambers, meters, and services to connect to the designated water supply source at the interface point. Treat water in accordance with UFC 3-230-02.

5-3.8.3 Water Treatment Equipment.

Provide a permanent water treatment system designed for continuous use. Design the water treatment system for automatic operation with minimal operator intervention. Include the option of providing a Reverse Osmosis (RO) unit, chemical-based treatment system, or combination of the two. The chemical-based treatment system is to include a dual-train demineralizer of the anion-cation type complete with regeneration equipment, piping, valves, and controls for treatment of public supply potable water, and industrial supply well water. Provide water treatment equipment to fulfill the following functions: boiler makeup water treatment; chemical feed systems; sampling systems; and, treated water storage.

Provide potable water for sanitary uses as required by applicable laws. Supply water for other facility needs from the following sources in the priority listed below:

- Blowdown from cooling towers (use for quench water for the bottom ash and dilution water for the scrubbers at a minimum);
- Harvested stormwater (as available);
- Industrial supply water (as available);
- De-chlorinated potable water; and
- Potable water (for selected process uses). Minimize to the greatest extent possible the need for potable water for non-sanitary usage.

5-3.8.4 Storage.

Store all harvested stormwater, industrial supply water, de-chlorinated potable water, and potable water in the facility recycle and reuse tank. Store cooling tower blowdown water in the facility’s wastewater tank prior to use at the facility.

5-3.8.5 Water Meters.

Install water meters to track water consumption (instantaneous and total) from all sources. Use electronic meters and track using the plant distributed control system. Comply with the local utility company’s metering requirements as well as the OUSD (AT&L) Utilities Metering Policy as detailed in the following website: (http://www.acq.osd.mil/eie/IE/FEP_Policy_Program_Guidance.html) and DoDI 4170-11 Installation Energy Management.

5-3.8.6 Treatment.

Provide water treatment for boiler make-up water, cooling tower make-up water, and auxiliary cooling water. Treat water to equipment system manufacturer's requirements.

5-3.8.7 Water Storage Tanks.

At a minimum, provide a condensate storage tank, demineralized water storage tank, auxiliary cooling water head tank (if applicable), flue gas condensate tank (if applicable), raw water storage tank (if applicable), firefighting water storage tank, wastewater storage tank, and any other miscellaneous tanks necessary to the design must be provided.

5-3.8.8 Centralized Chemical Sampling System.

Provide a centralized chemical sampling station in order to provide information on chemical conditions in the feed, condensate, steam, and cooling tower systems. Continuously draw samples from defined points and analyze automatically.

Design so that each analyzers is capable of an indication at the local sample panel and in the control room. An indication of chemical conditions that are out of the acceptable range must be communicated via an annunciator in the control room. Design the local sample panel to accommodate the taking of grab samples.

5-3.8.9 De-mineralized Water System.

Provide two (2) full capacity skid-mounted operational demineralizers. Each demineralization must be capable of producing the required quantity and quality of make-up water for the facility feedwater-condensate water system.

Design the demineralizer system for push-button automatic operation. The demineralized water is to conform to the boiler and turbine manufacturer's requirements. In addition to boiler makeup, this system is required to provide makeup as necessary to other plant systems. Utilization of a RO system followed by electro deionization to provide boiler make-up water is acceptable.

5-3.8.10 Water Storage Tank (Fire).

Design and install the fire water storage tank and site main systems. Size the fire pump, water supply, and fire water storage tank systems to supply the minimum fire flow required by code.

5-3.8.11 Auxiliary Cooling Water System.

Design an auxiliary cooling tower capable of operation at full capacity with one closed cooling water pump to dissipate heat. Include sufficient cooling capacity to accommodate loads identified in the final design. Provide a chemical feed system.

5-3.9 Residue Hauling and Storage System.

Provide a complete furnished and installed residue conveying system for each boiler/furnace/steam generating unit. Provide a common conveyor system, consisting of primary and secondary conveyors, to transport residue from each unit to the ash management building. Provide an adequate means of redundancy that would prevent the shutdown of more than one boiler/furnace/steam generating unit if a system component must be taken out of service. The system proposed must be amenable to separate collection of APC residue (fly ash and spent salts of reaction) and bottom ash without requiring building modification.

5-3.9.1 Design Criteria.

Design the ash system for the quantity resulting from waste processing at the Contractor-specified ash density but no less than 100 lb/ft^3 (1602 kg/m^3) density with suitable margin for upset and peak conditions. Use a reasonable ash design density for volumetric sizing and conveyor and structural sizing. Design the system to start under fully loaded conditions assuming a two-hour interruption in the ash handling system.

Provide the quantity and compositions of residue ash expected to be produced at the facility from the furnace/boiler and APC systems and ensure that this residue ash is not considered hazardous based on applicable laws.

5-3.9.2 Bottom Ash Conveyors.

Provide two 100% capacity ash conveyors to remove the bottom ash from the boilers and convey the bottom ash and fly ash to the ash management building. Provide a grizzly scalper on each bottom ash conveyor as well as any other redundancy measures deemed necessary to keep the boilers in operation if an ash system component is taken out of service.

5-3.9.3 Fly Ash Conveyors.

Under normal operating conditions, the APC fly ash is combined with the bottom ash in the ash management building following the metals recovery system. Provide two 100% capacity conveyors to transfer the APC fly ash from the APC fly ash collection equipment to the ash management building. Include provisions for combining the APC fly ash with bypassed bottom ash if the metals recovery system is not operational.

5-3.9.4 Metal Recovery Conveyors and Storage.

Design ferrous and non-ferrous recovery and associated conveying and storage facilities to accommodate the waste throughput design rate.

5-3.9.5 Wet Residue Removal System.

Discharge residue from the grates, boiler and economizer hoppers, and siftings from under the grates for each unit into a pusher type residue discharger. Design equipment to be capable of using wastewater from the other facility operations. Provide the pusher type residue dischargers with a quench tank equipped with a hydraulically operated residue pusher. Discharge residue from the residue pushers directly into the residue pit or onto a series of conveyors and convey the residue to a residue building. Design all system components with housekeeping and safety in mind.

5-3.9.6 Residue Storage.

Include concrete, drainable pits in residue storage facility for placing residue containers or trucks during loading operations. Residue containers must be enclosed, watertight and dust-proof so as not to present a hazard to either plant personnel or the general public while residue is being loaded and transported to the landfill. Fully enclose the loading station. In general, design all residue loading and unloading systems to be dust free and designed to meet the general requirements for residue loadout established by U.S. EPA. In particular, no visible emissions of dust from any doorway, window, vent, louver, or other opening is allowed.

5-3.9.7 Residue Pit.

Design the residue pit for a minimum of five days' usable storage of residue for a 1,500 tons (1400 metric tons) per day (tpd) facility. Completely enclosed residue pit and all conveyors external to buildings with a filtered ventilation system. Do not connect the residue pit to any other structures in such a fashion as to enable dust to infiltrate to other plant parts.

5-3.9.8 Truck Loading Station.

Design the truck loading station with a 1.0% slope from the truck loading zone to the ash storage bunkers. Install four (4) ft. (122 cm) wide by four (4) in (10 cm) high speed bumps at the entrance and exit ramps. Supply the entrance and exit ramps bases with a trench drain, draining back to the building sumps, to capture any potential ash or water spillage. Place bollards on both the inside and outside of all truck door openings. Provide a reinforced push wall surrounding the bunker areas and extending to the truck entrance and exit doors with a minimum height of 14 ft. (4.2 m). Line the inside building perimeter, excluding the bunker areas, with a reinforced concrete wall at a minimum of two (2) ft. (61 cm) high by one (1) ft. (30.5 cm) thick.

5-3.9.9 Fly Ash Collection System.

Design the APC fly ash collection system to collect APC fly ash from the scrubber and baghouse, which may include spent lime reagent, carbon reagent, and collected salts. Provide two, 100% capacity, conveyors to transfer the APC fly ash from the APC fly ash collection equipment to the ash management building. Combine APC fly ash with bottom ash only after the bottom ash has passed through the metals recovery system. The fly ash handling system is not limited to screw conveyors, but must be a commercially proven design.

Collect APC fly ash from each APC system hopper with drag or screw conveyors. Convey fly ash to the residue pit, conveyor, or residue building after the point of ferrous metal recovery from bottom ash and then to a residue conditioner for disposal. Semi-dry reactors may incorporate air slides for conveying APC fly ash from the baghouse to the scrubber for fly ash reuse purposes. Utilize screw conveyors or drag conveyors for conveying APC fly ash to the APC fly ash conditioning system. Provide a completely dust-tight APC fly ash drag or screw conveyor area to prevent leakage of APC fly ash.

5-3.9.10 Ventilation System.

Include exhaust hoods at transfer points connecting to a central dust control system for all ash handling equipment within the ash management building. Connect this central dust control system to a wet scrubber or baghouse. Design the ash management building with a separate ventilation system designed to permit a minimum of two air changes per hour. Comply with current ASHRAE HVAC Applications Handbook ventilations standards.

5-3.9.11 Instruments and Controls.

Design the residue handling systems to be fully automatic between the furnace and the residue storage pit or residue building. Provide sensors with alarms for readout and recorded on the Distributed Control System (DCS) in the central control room for any system failure.

5-3.10 Control and Instrumentation.

5-3.10.1 Central Plant Controls.

Provide a central plant DCS with redundant processors and local area network with automatic switchover to enhance reliability of the control system. Plant controls are to be operated from the central plant control room, and include boiler, turbine, feedwater and condensate system, condensing system and water treatment system controls. Provide management control stations at strategic points in the plan for maintenance and redundant control requirements. Provide automated subsystems for the following:

- Each boiler train for steam production and air pollution control;
- Turbine and thermal cycle;
- Electrical substation;
- Emergency shut down; and
- Balance of plant controls.

Integrate asset management and maintenance activities into the central plant control. Asset management functions are to interoperate with the control system to plan maintenance operations. Use information from the plant instrumentation to perform statistic predictive maintenance. The following systems are to be handled locally or are automated systems.

5-3.10.1.1 Waste Handling Crane.

Crane control is maintained at a stationary operating station also called the crane pulpit. Provide voice communication between the control room and the crane pulpit. Provide video feeds covering the waste storage pit to the control room.

5-3.10.1.2 Residue Handling System.

Design the residue handling system between the furnace and the residue storage pit to be automatic. Design other residue handling systems for locally manual control. Operating status of all conveyors must be indicated in the control room. Install video feeds of all conveyor paths to the control room.

5-3.10.1.3 Waste water discharge

Design for local control.

5-3.10.1.4 Chemical addition systems

Design for automatic and locally controlled.

5-3.10.2 Control Room.

Provide a central plant control room and include DCS operator stations, DCS engineering station, and asset management station. Provide inter-facility start-up from the control room, with select systems started locally as detailed in previous sections. Ensure operators are able to supersede the automatic controls and operate the facility manually from the control room. Back up normal plant control systems and procedures by separate interlocks or safety systems designed to effect action in cases of emergency.

5-3.10.3 Control Pneumatics.

Provide separate controls for plant air and instrumentation air. Design air compressor system to provide plant air and instrument air for the facility. Equip plant air piping system with automated shutoff valves to non-essential headers in the event of a loss of primary compressed air. Install air dryers with the capability of being bypassed for maintenance without shutting down both compressors and associated accessories.

Provide redundant full capacity air compressors with aftercoolers. Provide separate stand-by redundant compressors sized for critical equipment operation. Compressors and compressor motors must be provided with manufacturer's standard offering control system which must load and unload the compressors during operation. Compressor operation must alternate between the two (2) compressors during normal operation. If one air compressor trips, the control system will automatically place the stand-by compressor in operation without low air pressure trip. Cover all couplings and drives with metal guards.

5-3.11 Fire Protection.

Design and construct the fire protection systems in accordance with UFC 3-600-01, and NFPA 101 and 850 as modified by UFC 3-600-01. Design and construct systems to prevent and control explosions in accordance with NFPA 69 at the tipping floor, waste storage pit, and material storage silos created by flammable concentrations of gases, vapors or dusts created by waste processes or hazardous waste not removed during the waste processing.

5-3.11.1 Fire Fighting Control Room.

Provide a self-contained firefighting control room adjacent to the plant control room. Locate the master fire alarm control panel, parallel displays of the plant closed circuit television (CCTV) system, and fire fighter telephone master console system, elevator status panels, and fan override controls in the control room.

5-3.11.2 Fire Fighter Telephone System.

Provide a fire fighter telephone system in the plant where fire fighter radios will not operate to enable two-way communications and in key areas as directed by the local fire authority having jurisdiction (AHJ). Use a common communication talk line system.

5-3.11.3 Interior Sprinkler System.

Provide all interior areas with sprinkler systems.

5-3.11.4 Exterior Sprinkler System.

Provide dry sprinkler system at all exterior areas with process equipment. Provide fire sprinkler system at cooling towers unless cooling towers are non-combustible.

5-3.11.5 Monitor Nozzles.

In addition to a dry pipe sprinkler system located over the pit and charging hopper parapet, provide local and remote operation of high capacity monitor nozzles. Locate monitor nozzles to facilitate ease of access by, and provide safe distance, for firefighting personnel. Space monitor nozzles to provide 100% coverage of the tipping and pit floors, and arrange to avoid inadvertent impact by the crane grapple. Protect monitor nozzle piping systems exposed to freezing temperatures from freezing.

5-3.11.6 Fire Fighting Water Storage.

Design the fire pump system to pressurize the fire water site main and take suction from the fire water storage tank. Size the fire pump, water supply, and fire water storage tank systems to provide fire water protection requirements for a 3-hour duration, or more. Arrange for the installation of at least two (2) fire water pumps unless a risk analysis eliminates the need for redundancy. Consider pump failure modes, electrical system failure modes, fire and explosion spread potential, life safety risk to fire fighters and plant personnel, environmental impact, pump maintenance requirements and local fire authority having jurisdiction requirements in the analysis. Where redundant pumps are used, one of the pumps must be isolated in a fireproof enclosure. Wire the redundant pump for a priority power from an emergency diesel generator or drive pump with a diesel engine.

5-3.11.7 Fire Alarm and Signaling Systems.

Provide fire alarm and Mass Notification Systems (MNS). Fire alarm systems must conform to NFPA 72 and UFC 3-600-01. MNS are to comply with UFC 4-021-01.

5-3.11.8 Smoke Relief Hatches.

Large emergency smoke relief hatches (solenoid release operated) are to be provided in the roof above the parapet-pit area.

5-3.11.9 Deflagration Venting.

Conduct a hazard analysis and provide deflagration venting systems in accordance with NFPA 68.

5-3.12 Water Pollution and Control Equipment.

5-3.12.1 Water Pollution Control Requirements.

Stormwater drainage and collection for all site areas to comply with all State requirements including all appropriate notifications and filings. Collect stormwater inside the site area discharged to a predetermined location. Utilize gasketed stormwater piping in areas subject to plant operations contamination and route to the facility wastewater treatment plant.

5-3.12.2 Process Waste Water Pollution Control Requirements.

Provide an onsite wastewater collection and treatment system to meet the wastewater discharge quality limit for the facility, including treatment of all process wastes, spent chemicals, backwash and rinse waters. Design facility wastewater system to maximize water reuse and reduce discharges to a minimum.

5-3.13 Heating Ventilation and Air Conditioning (HVAC) Systems.

Provide heating, ventilation, and air conditioning to remove dust, remove radiated process heat, control odor, minimize condensation, and provide a safe and comfortable working environment. Keep normally occupied areas such as the offices, control room, and crane operator control room at positive air pressure in relation to plant machinery and solid waste operation areas. Design and construct facility HVAC systems in accordance with UFC 3-401-01, UFC 3-410-01, UFC 3-410-04N (for Navy), and ACGIH Industrial Ventilation: A Manual of Recommended Practice, as appropriate for the facility area classifications.

Provide HVAC systems as indicated in the following sections. Where air conditioning is not provided, calculate ventilation rates for heat removal in summer conditions not to exceed 104 ^{o}F (40 ^{o}C) where practical. When 104 ^{o}F (40 ^{o}C) is exceeded, ensure all equipment upper operating temperatures are considered in the design. Limit forced air ventilation to not to exceed 60 air changes per hour. Preheat outside ventilation air to prevent freezing of piping and plant equipment as appropriate.

5-3.13.1 Refuse Receiving and Storage Building.

Design the refuse receiving and storage building ventilation to provide a minimum of 12 air changes per hour. Provide filters and scrubbers on exhaust air.

5-3.13.2 Boiler Building.

Design the boiler building for operating temperature between 45-55 ^{o}F (7-13 ^{o}C) heating only and ventilation of a minimum of 30 air changes per hour below the burners and 15 air changes per hour above the burners. Provide multiple units. Source air through the refuse pit. Provide filters and scrubbers on exhaust air.

5-3.13.3 Control Room.

Design the control room for operating temperature between 72-76 ^{o}F (22-24 ^{o}C) cooling and 68-72 ^{o}F (20-22 ^{o}C) heating with relative humidity between 30 to 50%. Ventilation is to be per ASHRAE 62.1. Noise Criteria (NC) not to exceed 40. Provide two independent units for 100% redundancy. Control room air pressure to be positive to remainder of facility with filtration efficiency of 90% and ultraviolent (UV) sterilized.

5-3.13.4 Server Room.

Design the server room for operating temperature between 68-72 ^{o}F (20-22 ^{o}C) and relative humidity between 30 to 50%.

5-3.13.5 Crane Operator Control Room.

Design the crane operator control room for operating temperature between 72-78 ^{o}F (22-25 ^{o}C) cooling and 68-72 ^{o}F (20-22 ^{o}C) heating with relative humidity between 30 to 50%. Ventilation to be per ASHRAE 62.1. NC not to exceed 40. Provide two independent units for 100% redundancy. Control room air pressure to be positive to remainder of facility with filtration efficiency of 90% and UV sterilized. Provide a system with energy recovery units on exhaust air.

5-3.13.6 Steam Turbine Area.

Design the turbine area for operating temperature between 45-55 ^{o}F (7-13 ^{o}C) heating only and ventilation of a minimum of 10 air changes per hour.

5-3.13.7 Administrative Offices.

Design the administrative offices for operating temperature between 74-78 ^{o}F (23-25 ^{o}C) cooling and 68-72 ^{o}F (20-22 ^{o}C) heating with relative humidity between 30 to 50%. Where administrative offices are included in the main plant facility, the air pressure is to be positive to remainder of facility with filtration efficiency of 90% and UV sterilized. Provide energy recovery units on exhaust air.

5-3.13.8 Air Pollution Control Building.

Design the area for operating temperature between 45-55 ^{o}F (7-13 ^{o}C) heating only and ventilation of a minimum of 5 air changes per hour. Provide filters and scrubbers on exhaust air.

5-3.13.9 Ash Conveying Areas.

Design building for operating temperature between 45-55 ^{o}F (7-13 ^{o}C) heating only and ventilation of a minimum of five (5) air changes per hour but not less than that required to prevent explosive dust accumulation. Provide filters and scrubbers on exhaust air.

5-3.13.10 Residue Management Building.

Design the building for processing and storing ash, ferrous and non-ferrous metals, and oversized materials. Size the Residue Management Building for five days storage for processing, separating, and storage of non-ferrous and ferrous metals; and four days storage of ash. Determine the Residue Management Building dimensions based on operating and space requirements.

5-3.14 Plumbing Systems.

Design plumbing systems in accordance with UFC 3-420-01.

5-3.15 Electrical Systems.

Design plant electrical system as a unit type system with the utility transformers connected solidly to the generator bus and switched with the generator. Design electrical systems in accordance with UFC 3-501-01.

5-3.15.1 Utility Interconnect.

Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

5-3.15.2 Synchronizing Switchgear.

Provide a substation on the facility site of a modern, fenced, low-profile design, complete with bus duct connection between generator switchgear and facility step-up transformer. Protect all the electrical equipment from electrical fault damage by protective relays. Design substation to operate over the range from import of full station auxiliary power requirement to export of full net plant real and reactive power capability to the transmission system while maintaining standard operating voltage limits on the facility buses.

5-3.15.3 Electrical Power Distribution System.

Provide a complete electrical system of medium-voltage, low-voltage, and DC power to all loads in the power plant under all service conditions including start-up, operation, failures, and shutdown. Plant medium and low voltage distribution system are to be grounded wye. Provide parallel medium voltage to low voltage unit substations for redundancy. Plant critical loads include the following:

- Fire pumps;
- Fire jockey pumps;
- Uninterruptable Power Supply(ies) (UPS);
- DC power system and battery chargers;
- Cooling water pumps;
- Hydraulic pumps;
- Critical lubrication systems;
- Elevators;
- Security systems;
- Distributed control system;
- Control and server room HVAC systems;
- Motor control center and switchgear HVAC systems;
- Critical instrumentation;
- Telecommunication systems;
- Aviation obstruction lighting;
- Perimeter security lighting; and
- Emergency and exit lighting.

Design the system with the following criteria:

5-3.15.3.1 DC System.

Provide a DC system, with UPS, for the plant DCS to provide for an orderly facility shutdown in the event of a loss of normal power. The DC power is to conform to the requirements of UFC 3-520-05.

5-3.15.3.2 Emergency Power System.

Provide an emergency power system for operating the plant critical loads in the event of a loss of normal power.

5-3.15.3.2.1 Uninterrupted Power System

Provide a UPS for the following critical loads: fire alarm system and MNS; telecommunications system; security systems; plant DCS; and critical instrumentation.

5-3.15.3.2.2 Generator

Provide natural or diesel gas generator(s) if natural gas is not available, sized to handle the plant critical loads and an N+1 redundancy. If using diesel gas generator(s), provide a minimum fuel storage for operating at full emergency power for five (5) days.

5-3.15.4 Lighting.

Conform to UFC 3-530-01 and National Electrical Contractors Association (NECA)/IESNA 502-2006.

5-3.15.5 Grounding/Lightning Protection System.

Conform to the following: IEEE C2, IEEE 142, NFPA 70, NFPA 780, and UFC 3-575-01.

5-3.15.6 Communications and Signal Systems.

Conform to UFC 3-580-01.

5-3.16 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

5-4 OPERATION AND MAINTENANCE.

5-4.1 Non-Performance.

Ensure non-performance and remedy clauses are included in the maintenance contract to address contractor non-conformance. Ensure liquidated damages address loss of power generation revenue and mission impacts.

5-4.2 Warranties.

Specific component warranties will vary with manufacturer. Arrange for a five (5) year extended warranty period after date of project acceptance for the following major equipment and sub-systems: scales, cranes, steam generating systems, APC systems, DCS system, CEM systems, turbine-generators, condensers, cooling towers, and feedwater-cooling tower pumps. Warranties are typically limited to repair or replace, at manufacturers' discretion, the defective components, or assemblies. Warranty limits may include causes for materials, supplies, and equipment not manufactured or supplied by the manufacturer, unauthorized repairs or modifications, Acts of God, and incidental or consequential damages.

5-4.3 Power Plant Operation.

Design plant so that each boiler/generator unit may be operated independently, and a single failure of mechanical equipment common to all boiler / generator units will not trip any operating boiler/generator unit.

The plant and each boiler/generator unit is to be fully dispatchable with automatic generation control (AGC) and capable of being dispatched from minimum to full load. The facility and each Unit will also be capable of cycling operation. The balance-of-plant design will not limit operation over the full range of site ambient conditions.

5-4.4 Maintenance Requirements.

Provide for and equip maintenance facilities with required tools and repair plant equipment. Organize the maintenance facility that is organized into defined work spaces. Provide hoists/monorails as required for the shop. Size maintenance area doors to accommodate expected maintained equipment sizes. Work spaces to include, at a minimum, a machine shop, hot work area, vehicle maintenance and storage garage, and painting work area with ventilation. Maintain critical spares as necessary to meet mission reliability/availability requirements.

5-4.5 Safety.

Comply to applicable provisions in 29 CFR 1910 and 29 CFR 1925, American Conference of Governmental Industrial Hygienists Threshold Limit Values and Biological Exposure Indices, and local/agency codes and requirements.

CHAPTER 6 DESIGN CRITERIA – LANDFILL GAS RECOVERY POWER PLANT

6-1 INTRODUCTION.

This chapter presents the planning, design, O&M requirements, and equipment calibration for renewable energy produced by landfill gas collection and processing systems.

6-1.1 Technology.

Use technology that utilizes waste gas (from landfills) to energy technology of low-grade, medium-grade, and high-grade landfill gas. Use resources and references specifically for a medium-grade landfill gas system.

6-1.2 Landfill Gas (LFG) To Energy.

Refer to USEPA for various applications for LFG to energy (http://www.epa.gov/lmop). USACE EM 200-1-22, as amended by Agency guidance, provides information on systems design to monitor, collect, transport, and treat LFG from landfills.

6-1.2.1 Land Fill Gas Overview.

Employ systems and technologies associated with analyzing, extraction, collection, processing, and treatment of LFG, produced by decomposing organic waste, and then converted into a useable energy source. Provide the aforementioned systems to have the capability to simultaneously lower the quantity of greenhouse gas emissions released into the atmosphere and nuisance odors.

6-1.2.2 Landfill Gas Systems Types.

Passive Collection Systems: Utilize passive collection systems for control of migrating gases through the use of vertical and horizontal wells, liners, vents with all applicable appurtenances.

Active Collection Systems: Utilize active collection systems for the collection of LFG by mechanical means to create a vacuum to influence the gases to a desired location through the use of blowers or vacuums, vertical and horizontal wells, vents, valve systems, controls and analyzers, and with all applicable appurtenances.

6-1.2.3 Landfill Gas Grades.

Determine landfill gas quality grade to produce based upon end use specifications.

6-1.2.3.1 Low-Grade.

Low-grade LFG requires only minimal processing to remove moisture and particulates and produces a low-grade fuel that may be adequate for the facility operational requirements.

6-1.2.3.2 Medium-Grade.

Providing medium-grade LFG requires increased level of processing to remove moisture, volatile organic compounds (VOC), siloxanes, and sulphur compounds. Medium-grade LFG is used for most heating applications and electricity generation.

6-1.2.3.3 High-Grade.

Processing LFG to a high-grade quality requires removing moisture, particulates, VOCs, sulphur compounds, siloxanes, halogenated compounds, carbon dioxide, nitrogen, and oxygen. Process LFG to high-grade when pipeline quality is desired.

6-2 PLANNING.

Perform proposed and final siting coordination with OSD. 32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination with OSD is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil to avoid invalid site selections.

6-2.1 Waste Type and Quality Site Assessment.

Overestimating available LFG resources is a common project pitfall. Perform site due diligence and conservatively estimate recoverable methane quantities and quality by using up to date computer simulation software.

6-2.1.1 Composition.

Confirm that landfill composition has sufficient organic material, such as yard waste, food waste and sewage waste, suitable for bacterial growth, and avoid hazardous wastes.

6-2.1.2 Moisture Content.

Evaluate the landfill moisture content because the moisture content is a major factor of methane generation. Provide important data such as weather conditions, initial waste moisture, liner design, leachate collection systems, and cover types. The optimum moisture content should be in the 50% to 60% range.

6-2.1.3 Temperature.

Analyze landfill temperature. Evaluate the landfill depth to predict temperature fluctuations in the landfill since deep landfills provide more stable temperatures whereas shallow landfills are affected by surface weather conditions causing greater fluctuations in temperature. Optimum temperature for aerobic decomposition is 130 ^{o}F to 160 ^{o}F (54-71 ^{o}C) and for anaerobic decomposition are 85 ^{o}F to 105 ^{o}F (29-40 ^{o}C).

6-2.1.4 pH.

Analyze the landfill pH as methane generation is maximized when the landfill pH is neutral. The pH is generally in the range of 6.5 to 8.0 during methane generation. Leachate pH range is expected between 5.0 and 9.0.

6-2.1.5 Waste Density and Particle Size.

Confirm the waste density, which is a factor of waste size and compaction techniques.

6-2.1.6 Waste Age.

Confirm the landfill age, since landfill gas generation is typically significant for 10-20 years. Landfills with an age greater than 20 years are less likely to produce large quantities of landfill gas.

6-2.1.7 Moisture Access.

Evaluate means of access for water entry into the landfill in order to calculate and predict moisture levels within the waste.

6-2.2 Landfill Gas Generation Modeling.

Scholl Canyon and EPA-600/R-05/047 LandGEM models are the preferred models for use by the U.S. EPA and USACE respectively. Use the Scholl Canyon Model (First Order Decay) to determine the amount of methane produced by calculating the amount of waste disposed each year and the amount time after the landfill is closed, which are the primary variables required. Use the LandGEM Model which modifies the Scholl Canyon Model by dividing the waste by a factor of 10.

Perform a pump test for landfill sites with a large potential of LFG quantities and recovery. The tests should consist of installing extraction wells, blowers, and monitoring probes to collect and analyze the gas composition. The test results must include LFG flow measurements, landfill pressures, and the final calculated LFG production rate.

6-2.3 Landfill Gas Quality.

The preferred LFG composition consists of 40-60% methane (CH_4) and the remainder mostly comprised of carbon dioxide (CO_2). Evaluate and design system based upon LFG quality and quantity. Adhere to the following quality criteria in the analysis:

6-2.3.1 Saturation Water (Water Vapor).

The preferred quantity of saturation water vapor within the LFG is 4-7% by LFG volume created.

6-2.3.2 Sulfur Compounds.

Process and filter LFG to keep sulfur compounds within acceptable limits set forth by the monitoring equipment's manufacturer's recommendations.

6-2.3.3 Siloxanes.

Process and filter LFG to keep siloxanes within acceptable limits set forth by the equipment manufacturer's recommendations.

6-2.3.4 Halogenated Compounds.

Process and filter LFG to keep halogenated compounds within acceptable limits set forth by the equipment manufacturer's recommendations.

6-2.3.5 Volatile Organic Compounds (VOCs).

Process and filter LFG to keep VOCs within acceptable limits set forth by the equipment manufacturer's recommendations.

6-2.4 Environmental Regulations and Restrictions.

6-2.4.1 Resource Conservation and Recovery Act (RCRA) Requirements.

Comply with RCRA requirements if LFG is emitted or if condensate is treated and disposed. Comply with:

- 40 CFR Part 258;
- 40 CFR Part 260;
- 40 CFR Part 261;
- 40 CFR Part 262; and
- 40 CFR Part 268.

6-2.4.2 Air Quality Regulations.

Comply with local Air Quality Board requirements.

6-2.4.3 National Ambient Air Quality Standards (NAAQS).

Comply with NAAQS standards.

6-2.4.4 Clean Air Act (CAA).

Comply with CAA, including:

- 40 CFR Part 60;
- 40 CFR Part 63;

- New Source Review (NSR) permitting;
- 40 CFR Part 70, Title V permitting; and
- Information collection authority used to implement greenhouse gas reporting program.

6-2.4.5 Water Quality Regulations.

Comply with Clean Water Act (CWA) regulations.

6-2.4.6 Solid Waste Disposal Regulations.

Comply with landfills RCRA requirements.

6-2.4.7 Other Restrictions and Requirements.

Consult with states and local authorities that may have adopted rules concerning LFG emissions and condensate disposal to ensure compliance with all applicable regulations. Monitor emissions and comply with personnel exposure threshold limits.

Comply with industry standards and equipment manufacturer specifications where codes do not govern specific equipment or system features.

6-2.4.8 Nuisance Odor.

Provide a design to efficiently collect LFG, without overpull, to minimize the gas release to the atmosphere causing nuisance odors. Hydrogen Sulphide is a trace compound found in LFG within a typical range of 100 parts per million (ppm).

6-2.4.9 Vegetation Stress.

Monitor signs of vegetation stress due to high levels of oxygen or other gases which indicate an imbalance in the system or possible loss of control components.

6-2.4.10 Potential Explosive Gas.

Use infrared LFG analyzers to monitor methane levels at the landfill perimeters and other structures on or adjacent to the landfill and to initiate alarms and safe shutdown procedures before the lower explosive limit (LEL) of methane in air (5%) is reached.

6-2.4.11 Greenhouse Gas Release.

The design must incorporate redundant equipment, redundant extraction methods and LFG destruction schemes, and control systems to prevent greenhouse gas release to the atmosphere.

6-2.5 Interconnect Studies.

Perform interconnect studies. Refer to Chapter 8 titled "UTILITY INTERCONNECTION" for guidance.

6-2.6 Permits.

Confirm all Federal, State, and local permitting requirements prior to the design and construction of a landfill gas to energy project.

6-2.6.1 Environmental Impact Statement.

Provide an Environmental Impact Statement (EIS) which is a required document describing how the human environmental quality is affected both positively and negatively. This document must discuss how the environment is affected and the environmental consequences associated with the project. Provide a list of required alternatives that are to be included in the document. Include the following in the EIS:

- All required air permits;
- Any required construction permits are required for new LFG projects under the NSR;
- All documentation regarding the Prevention of Significant Deterioration (PSD);
- Title V operating permit;
- A National Pollutant Discharge Elimination System (NPDES) permit which regulates point sources that discharge pollutants into United States waters and include separate permitting for storm water run-off associated with the landfill;
- Solid waste disposal permits as required for the project and as required by the local authorities; and
- Dredge and Fill permits as required to meet the CWA Section 404 which regulates the discharge of dredged or fill materials into the United States waters.

6-2.7 Cost Estimation / Analysis.

Cost analyses for landfill gas entail unique cost estimation requirements and parameters including waste tonnage estimation, landfill gas collection efficiency, greenhouse gas (GHG) emission reductions, annual fixed and variable O&M costs, and calculation of capital costs.

6-2.7.1 Waste Tonnage Estimation Methodology.

Use waste tonnage estimation methodology to predict the total quantity of LFG output for a landfill over a set period based on the amount of LFG produced each year versus the amount of waste added each year. The estimation must show the increasing and decreasing quantities of LFG produced over the landfill life in relation to the increasing and decreasing quantities of waste added each year.

6-2.7.2 LFG Collection Efficiency Estimation Methodology.

Use the LFG collection efficiency estimation methodology to determine the average amount of LFG collected in a year divided by the LFG generation that was modeled for that same year. The LFG flow composition is assumed will be 50% methane. The LFG collection and management systems efficiency is expected to be a minimum of 75%.

6-2.7.3 Greenhouse Gas Emission Reductions.

Comply with the CAA emission regulations and implement the greenhouse gas reporting program.

6-2.7.4 Capital Costs.

The capital cost associated with constructing an LFG to energy project are typically $1,000 per kilowatt of electricity produced.

6-2.8 Coordination.

Establish an institutional framework consisting of the major project stakeholders including government authorities, the landfill owner / operator, community groups, and energy sector companies. Review with the stakeholders the financial, environmental and energy plant operational issues. Perform a comprehensive stakeholder analysis to identify potential issues involving energy plant construction and operation. Establish agreements that resolve issues before the plans are made to build the plant.

6-3 DESIGN CRITERIA.

6-3.1 General Design Requirements.

Design landfill gas recovery systems to extract the landfill gas through a gas collection system of piping and wells. Design the condensate in the landfill piping to be collected and treated through a condensate collection and treatment system. Design a primarily active type system were gas in the collection piping is pulled by vacuum blower(s) to an extraction plant where the gas receives further treatment to remove contaminants and improve the gas quality and while the condensate entrained in the gas is separated and filtered out. Include gas conditioning and filtering prior to being, burned in a flare, burned in a boiler to produce heating, or burned in a generator that powers an alternator to produce electric energy. Consider site climate to determine if equipment should be enclosed in a structure.

6-3.1.1 Site Considerations.

Investigate the site to determine the landfill elevation at which the landfill collects waste, in relation to the surrounding grade. Consider the elevation at which the landfill collects waste, in relation to the surrounding grade, which can affect the quantity of LFG collected, gas released to the atmosphere, and migration of gases to surrounding areas. Design slopes around collected waste to be more gradual and less acute and not to exceed 25% (4 horizontal to 1 vertical unit) to provide increased collection, efficiency, decrease potential for oxygen overpull, and increase simplicity for cover construction and maintenance.

Provide service roads. Design the site to provide proper vehicle access for by service personnel and emergency vehicles. Use a perimeter fence with lockable and accessible gates, at a minimum, to secure facilities and remote pieces of equipment. Ensure access is available to fire hydrants or other fire protection features. Provide all necessary utilities, such as sanitary sewer, water, electricity, and telecommunications, required for plant operations. Refer to UFC 3-600-01 for additional guidance.

6-3.1.2 Hydro-geological Condition.

Investigate site hydro-geological conditions to assess off-site LFG migration to determine high and low permeability materials, depth of ground water, moisture content, and other geologic conditions. See Table 6-1 below for suggested parameters and test methods. USACE references are mandatory for U.S. Army. For other Agencies, comply with agency specific requirements.

Table 6-1 Parameters and Test Methods for Landfill Gas Migration

Parameters and Test Methods for Landfill Gas Off-Site Migration (Adapted from USACE EM 200-1-22 table 2-1)		
Parameter Tested:	**Collection Method:**	**Reference:**
Atterberg Limits	Soil Borings	ASTM D4318
Depth to Groundwater	Monitoring Wells	ASTM D4750
Grain Size and Porosity	Soil Borings	ASTM D422
Heterogeneity / Utility Trenches	Geophysical Investigations	USACE EM 1110-1-1804
Moisture Content	Soil Borings	ASTM D2216
Stratigraphy	Soil Borings	ASTM D2487 ASTM D2488 USACE EM 1110-1-1804
Vapor Phase Concentrations	LFG Monitoring Probes	EPA TO 14a

6-3.1.3 Landfill Cover Design.

Design cover to prevent intrusion of air into the waste. Design must consider the effects of changing barometric pressures. Design the cover to prevent air intrusion into the waste to prevent oxygen overpull. Refer to UFC 3-240-10A (for Army) for final cover design. For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance.

6-3.1.4 Landfill Liner Design.

Refer to UFC 3-240-10A (for Army), for landfill liners design. For other Agencies, use UFC 3-240-05A as a reference and comply with Agency specific guidance.

6-3.1.5 Moisture Addition and Leachate Recirculation.

Introduce moisture to landfill or recirculate leachate as required to optimize LFG production by accelerating decomposition and to remove water soluble contaminants in the waste. Contaminants in the landfill can be removed by moisture percolating through the waste.

6-3.1.6 Oxygen Overpull.

Use monitoring equipment in the extraction well to assess the oxygen content in the LFG. The monitoring equipment must be capable of measuring the oxygen content to help determine oxygen overpull, locate possible leaks in the processing equipment, balance the wells to achieve the LFG quality desired, and to improve the extraction process efficiency. Oxygen levels should be less than 2.5% by volume.

6-3.1.7 Drilling Rig Access.

Provide adequate access, service roads, and space for the mobilization of drilling equipment and for drilling equipment usage when drilling LFG extraction wells.

6-3.2 Collection System Design.

Refer to USACE EM 1110-1-4016, or Agency specific guidance, for landfill gas collection system design.

6-3.2.1 Active Systems.

Design an active LFG collection system to consist of a blower system, extraction wells, a piping system with valves, flares, and electronic controls and meters. Use blowers to draw the LFG from the extraction wells through the piping system and delivered to the extraction plant where the gas is processed and combusted. Use an active system to capture and collect LFG.

6-3.2.2 Passive Systems.

Design a passive LFG collection system to consist of horizontal trenches filled with a coarse granular fill. Use passive systems only to supplement an active system and be used to prevent LFG from migrating out of the landfill to the surrounding soils or out to the atmosphere. Design passive systems to be located at the perimeter around the landfill and at shallow areas of the landfill.

6-3.2.3 Collection System.

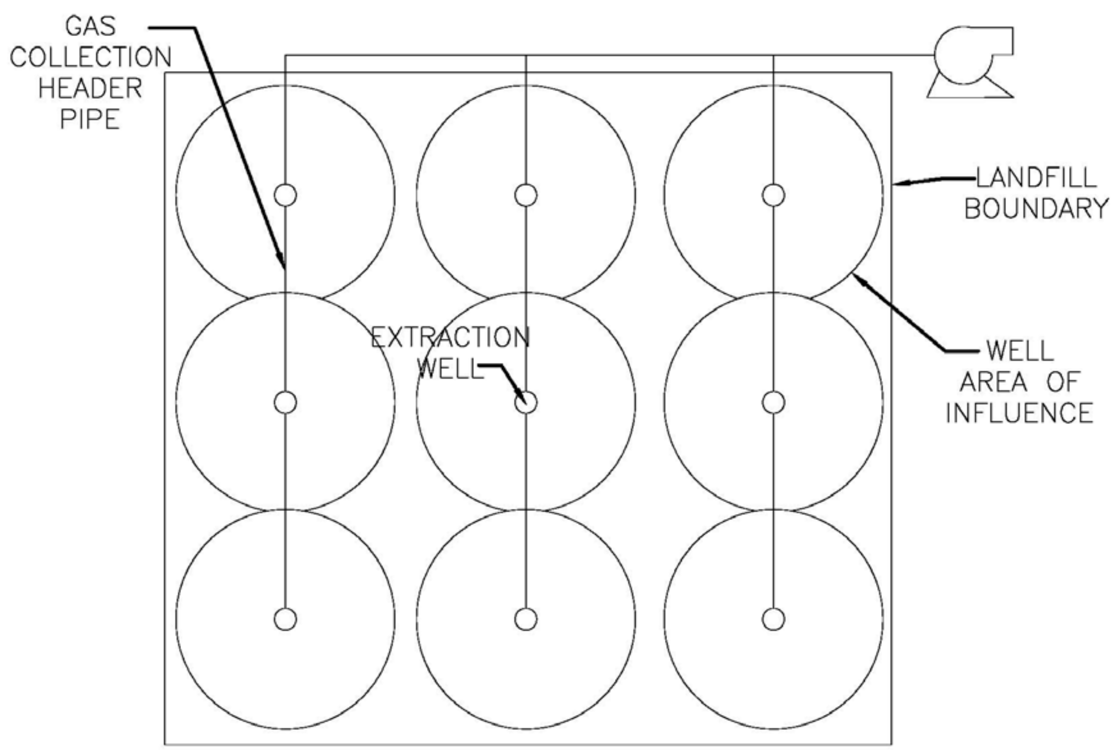
Collect landfill gas using a blanket collection system consisting of vertical extraction wells, and possibly with a combination of horizontal collection trenches. A blanket collection system consists of collecting LFG through a permeable layer of sand or gravel that is covered by an impermeable layer, a drainage layer, and a soil cover layer. A preferred permeable layer thickness is 1.0 ft. (30 cm) thick. Install a perforated pipe in the permeable layer connecting to a vent pipe. Space vent pipes 200 ft. (61 m) apart.

6-3.2.4 Vertical Extraction Wells.

Use vertical extraction wells primarily to extract LFG after landfill filling operations have been completed. Design vertical extraction wells to consist of perforated or slotted pipe that penetrate near the refuse bottom or near the saturated waste depth. The typical minimum depth of a landfill using vertical extraction wells is 40 ft. (12 m). Investigate the specific site confirm landfill depths and ensure a proper design.

Use the design procedures in USACE EM 200-1-22, or Agency specific guidance, and State regulatory requirements when determining the well spacing. Design vertical collection wells for 50 to 200 ft. (15-61m) spacing (Figure 6-1).

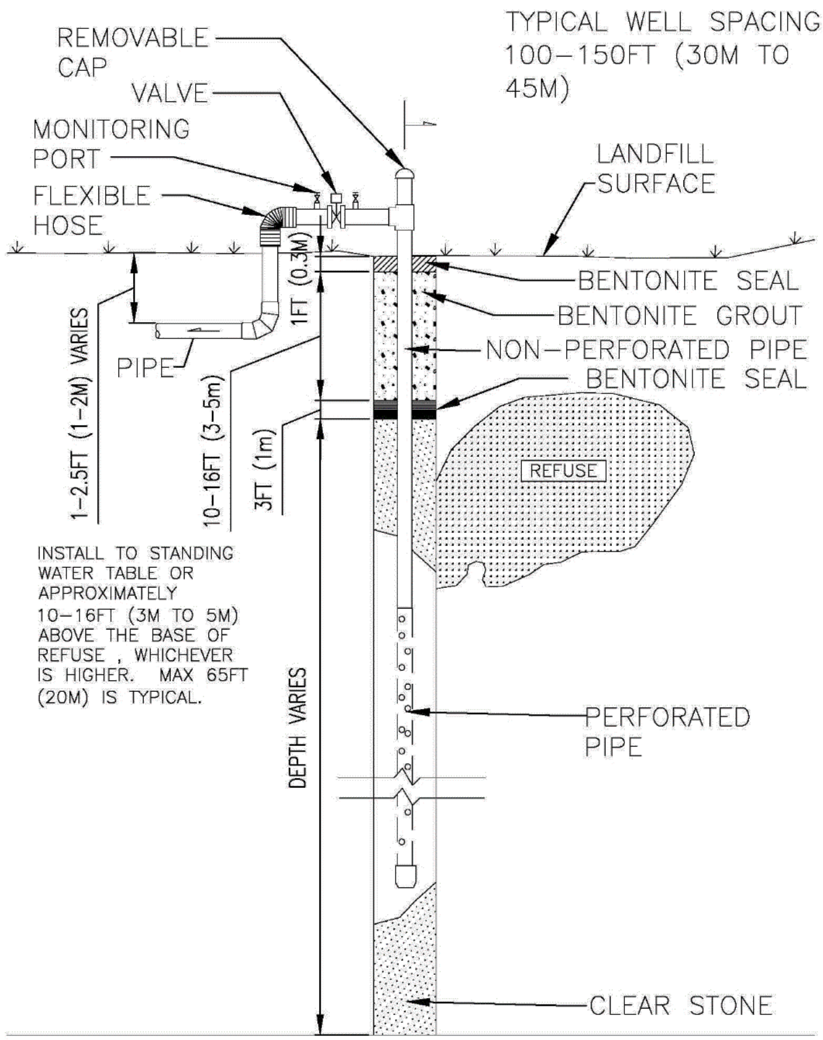
Figure 6-1 Well Spacing



6-3.2.5 Vertical Extraction Well Design.

Design a well to have a perforated pipe installed in the borehole center and then backfilled with an approved aggregate with a bentonite seal used to prevent air infiltration. Backfill the remaining borehole with soil. Analyze the LFG production rate and the radius of influence around a well to properly design the well system. The LFG recovery rate from a single well is expected to range from 10 – 50 cubic ft. per minute (cfm) (4.7- 23.6 l/s). The recommended design vacuum pressure for each extraction well is 10 – 25 in (25.4-63.5 cm) of water column (wc) to achieve higher LFG collection efficiency and to prevent a landfill fire or explosion. Where possible, design for higher efficiency operations to maximize the radius of influence while minimizing air (oxygen) intrusion into the landfill (Figure 6-2).

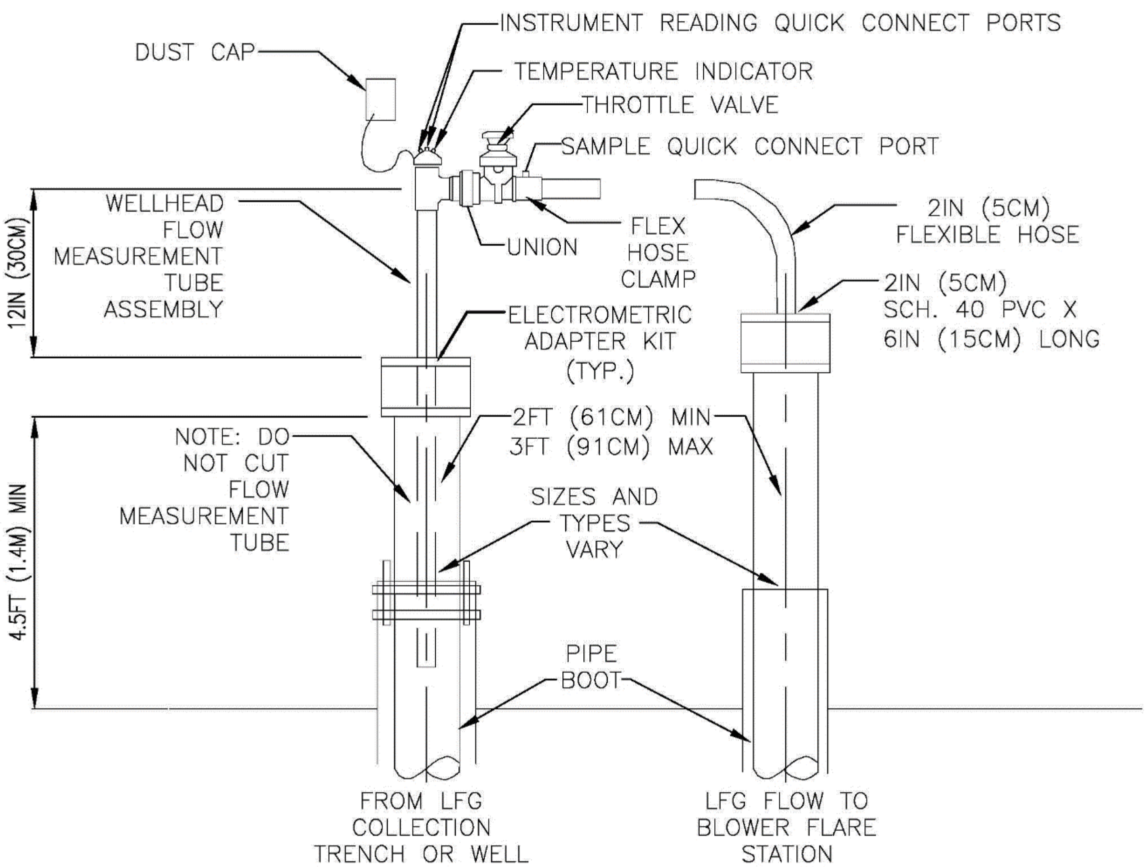
Figure 6-2 Typical Vertical Extraction Well



6-3.2.6 Vertical Extraction Well Heads.

Locate the well head assembly (Figure 6-3) above the landfill surface to allow for LFG sampling, measurement, adjustment, and inspection. Construct the well head assembly to incorporate a flow measurement tube, instrument connections, a sampling port, a control valve, a flexible hose, and a removable access at the perforated pipe top for inspection, maintenance, and leachate removal. Design pipe sleeves and boots for piping penetrating into extraction well. Size the control valve, or well head valve, to provide a high degree of control precision without over sizing valves. Preferred control valve types are butterfly and globe valves. Only use gate valves for isolation or on/off operation.

Figure 6-3 Well Head Assembly



6-3.2.7 Horizontal Collection Trenches.

Horizontal Collection Trenches. Use horizontal collection trench systems (Figure 6-4) for active landfills currently receiving waste or in shallow areas of the landfill. Use the horizontal trenches as part of the active type system. Limit passive type horizontal trenches to landfill perimeters only. Install the collection trenches in layers as the refuse is added (Figure 6-5).

Figure 6-4 Horizontal Collection Trench

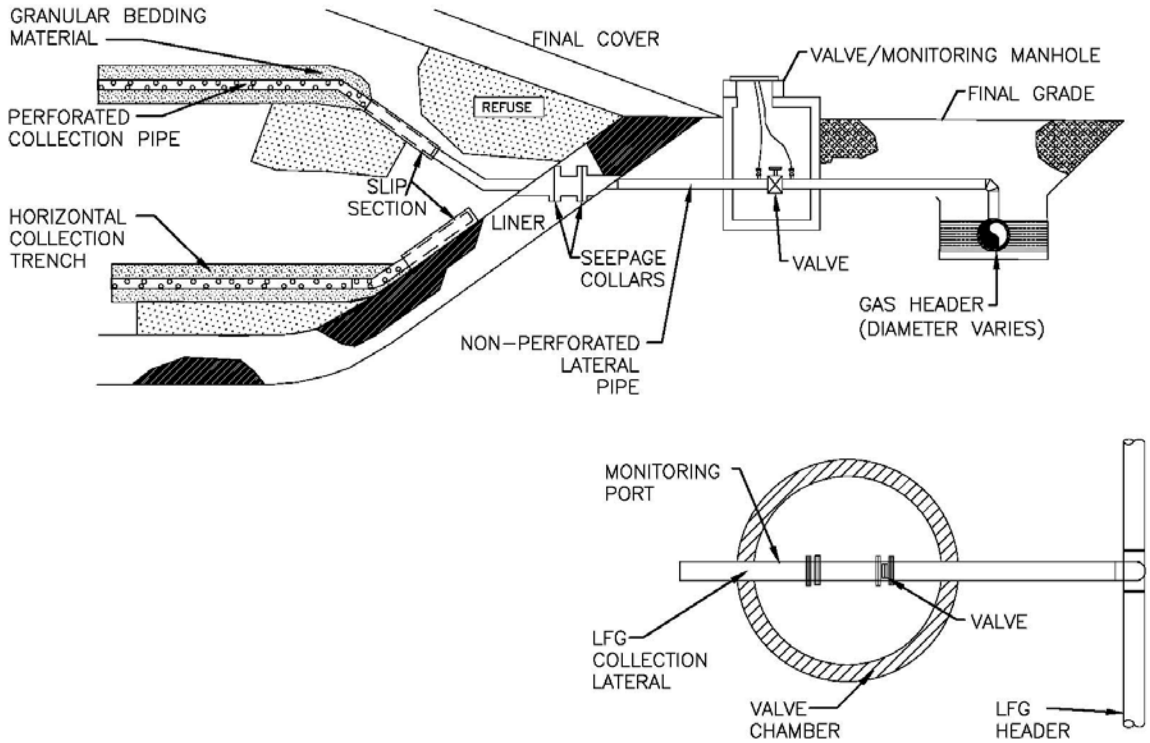
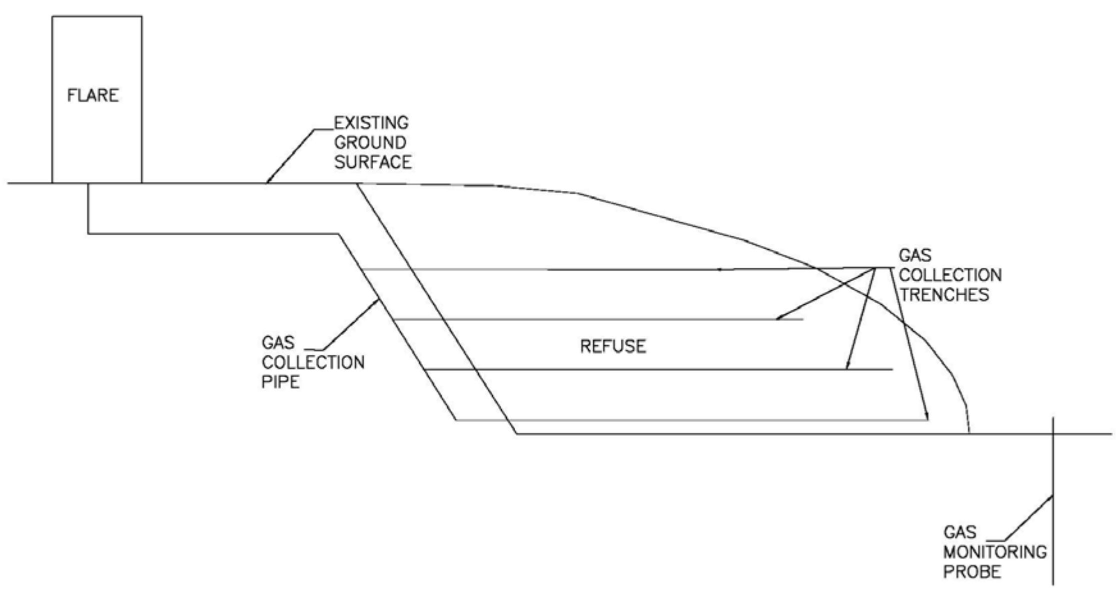


Figure 6-5 Horizontal Trench Layering



6-3.2.8 Horizontal Collection Trench Design and Construction

Refer to the design procedures in USACE EM 200-1-22 and State regulatory requirements when determining the well spacing. Space wells 200 ft. (61 m) apart.

Trench horizontal wells into the landfill using an approved aggregate bedding with a perforated pipe in the center of the trench. Backfill the trench with an approved aggregate. Apply a geotextile fabric on the trench top to prevent clogging. Use a bentonite seal to prevent air infiltration and back fill the trench with soil or waste. Construct the well head assembly similar to the configuration described for the vertical extraction well head.

6-3.2.9 LFG Collection Piping.

Design collection piping to transport LFG from the extraction wells, using blowers, to a burner or to a gas processing system prior to the end use equipment. Use a pipe header system to connect multiple extraction wells together. Design the LFG collection piping for below grade, wherever possible, to minimize condensate freezing and pipe clogging.

6-3.2.10 Header Configurations.

Take into account in the header configuration design, system components, landfill size and depth, types of waste, radius of influence, system friction losses in equipment and the subsurface components, and the extraction rate of LFG. Use one or more of the following three preferred methods for header configurations: (Figure 6-6).

6-3.2.10.1 Branch (Radial).

Design the branch header configuration to consist of a series of subheaders (branches) that connect to one main collection header. Use isolation valves to isolate individual branches for maintenance and service without shutting down large portions of the collection system.

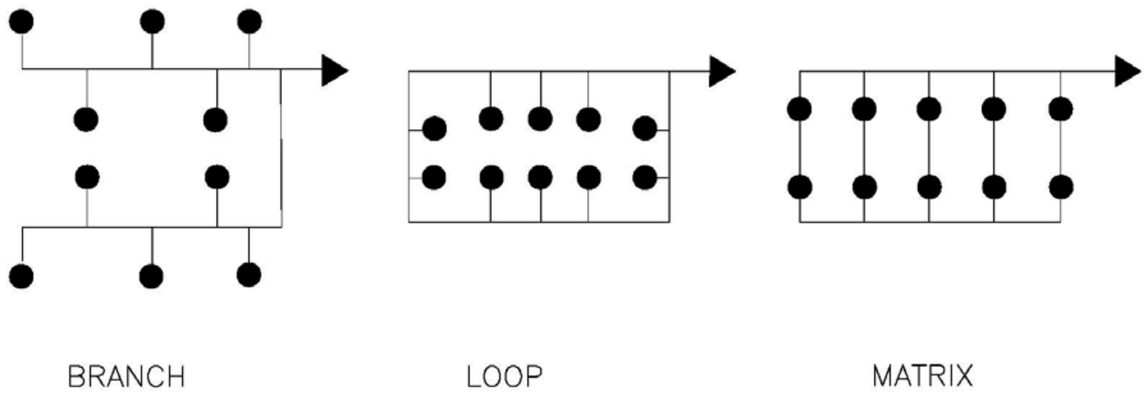
6-3.2.10.2 Loop.

Design the loop header configuration to consist of a main header that loops around the landfill with each well inside the loop connecting to the main header. Use isolation valves to shut down individual wells without shutting down major portions of the collection system. Ensure the design has adequate capacity to allow the LFG to flow in more than one direction.

6-3.2.10.3 Matrix (Herringbone).

Design the matrix header configuration to consist of a main header that loops around the landfill with the subheaders connected to the main header at both ends of the subheader. Connect the wells to the subheader that connect to the header. Use isolation valves to isolate individual subheaders for maintenance and service without shutting down large portions of the collection system. Ensure the design allows the LFG to have the capability to flow in more than one direction.

Figure 6-6 Typical Header Layouts



6-3.2.11 LFG Piping.

6-3.2.11.1 Sizing.

Size the piping system to have a frictional pressure drop, in the pipe, less than 10 in (25.4 cm) of water column with respect to the varying flow rates of LFG.

6-3.2.11.2 Header.

Slope the LFG header and subheader piping allow the condensate to adequately drain to a collection point and to prevent condensate collecting in pipes and potentially clogging the pipe. Provide 3- 5% slope in header and subheader piping. Design system to accommodate waste and soils settlement and account for settlement when determining pipe slopes.

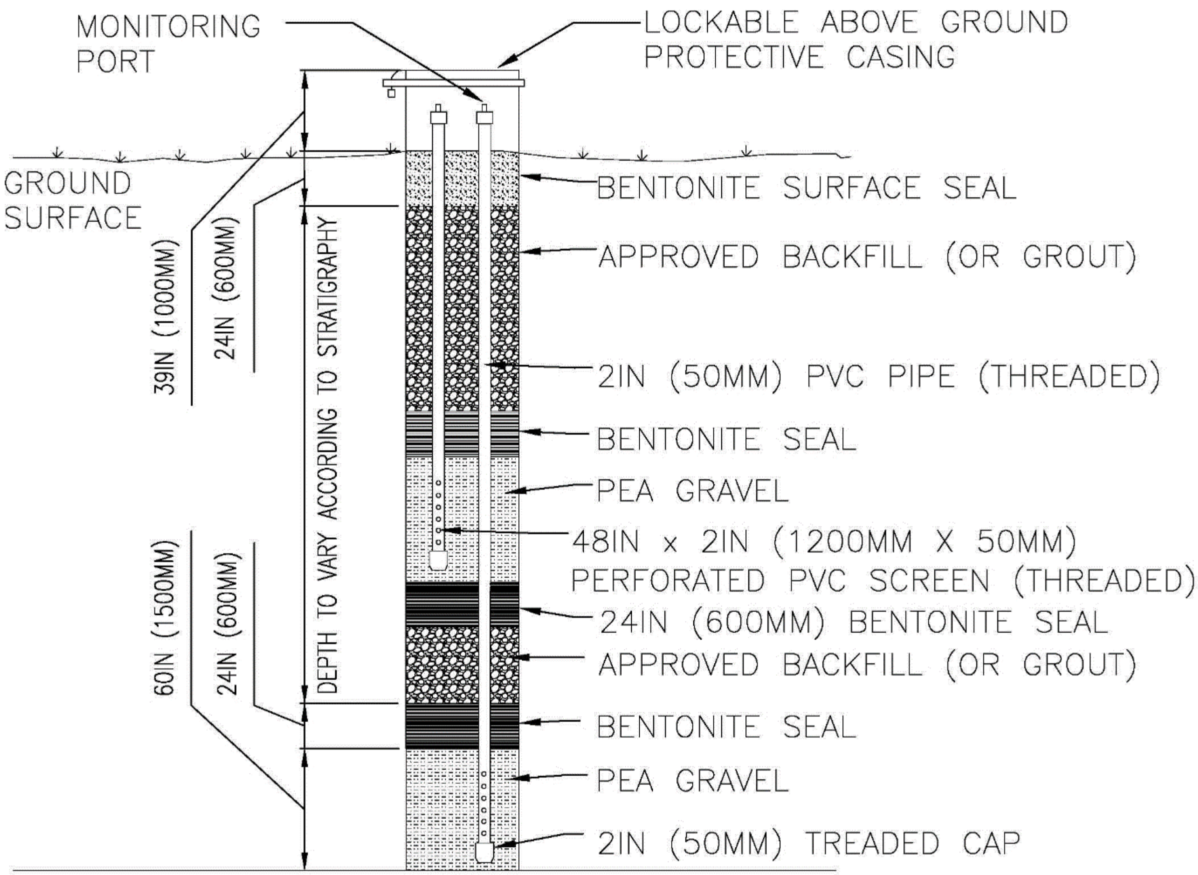
6-3.2.11.3 Materials.

Use polyvinyl chloride (PVC) or high density polyethylene (HDPE) pipe. HDPE is the preferred pipe type due its ability to withstand settlement damage and is less susceptible to damage from ultraviolet radiation than PVC.

6-3.2.11.4 Monitoring Probes.

Provide gas monitoring probes along the landfill perimeter to monitor LFG migration outside of the landfill and possible migration into adjacent structures. The preferred gas monitoring probe is a multilevel / multiple probe type to more accurately assess the migrating gases by defining the gas vertical profiles. Figure 6-7 illustrates a typical design of a multilevel / multiple gas probe.

Figure 6-7 Typical Gas Monitoring Probe Installation



6-3.3 Condensate Collection and Treatment System in LFG Collection Systems.

LFG condensate forms in the piping headers and subheaders. Design system to flow freely without blocking the pipe. Size the collection piping to allow for LFG and condensate to flow within the same pipe, and at times where the flow of LFG and the flow of condensate are in opposing directions. Provide for condensate collection low points. Provide air traps to avoid air intrusion into the waste. Use sump pumps to pump the condensate to a designated storage tank or treatment system for proper disposal or redistribution back into the landfill.

Provide for treatment and moisture / particulate filtering upstream of the blower to prevent damage to equipment and to ensure effective combustion at the flare. A condensate knockout system is the preferred type, to lower the velocity of LFG to allow an opportunity for the condensate to separate from the gas.

6-3.4 Extraction Plant.

Design an extraction plant consisting of equipment necessary to collect the LFG and primarily treat the LFG prior to being combusted for electricity generation or transmission.

6-3.4.1 Facility.

Design facility to effectively extract LFG from the landfill, remove condensate and particulates, combust the gas or divert the gas for electricity generation, and allow for adequate access and space for maintenance. Use blowers to create a negative pressure to extract LFG from the landfill and provide positive pressure to transport LFG to the flare where the gas is combusted, or for further treatment and use for electricity generation. Use flares to combust LFG for effective gas control and prevent LFG release to the atmosphere. Provide all controls, instrumentation, and monitoring equipment necessary for effective collection and processing of LFG.

6-3.4.2 Components.

6-3.4.2.1 Condensate Knockout and Particulate Removal.

Use a simple drum type condensate knockout system where low pressure centrifugal blowers are used for LFG extraction. Provide filters to remove particulates out of the LFG. Stainless steel or plastic mesh screen filters are preferred for particulate removal and added moisture removal.

6-3.4.2.2 Blowers.

Use centrifugal or positive displacement rotary lobe blowers recommended by USACE EM 200-1-22 or Agency guidance. Provide explosion proof blowers suitable for NFPA 70, Class I, Division I, Group D. Provide anti-corrosion protective coating for blower components in contact with landfill gas. Provide a full redundant unit for equipment maintenance and downtime as needed to avoid any potential health hazards. Design the blower system to take into account the LFG piping arrangement, sizes, flow rates of LFG, the pressure losses in the system piping and wells, the pressure losses in the system components, and all other system effects.

6-3.4.2.3 Gas Condenser (Refrigerated Dryer).

Use a gas condenser to further process the landfill gas by removing water vapor and organic impurities and to improve the combustion efficiency. Condensers utilizing a refrigerated system to cool the LFG to its dew point temperature to condense the water vapor out of the LFG stream are preferred. Use a refrigerated system that will bring the dew point for LFG down to 36 ^{o}– 38 ^{o}F. Use a gas condenser system that will remove impurities that are water soluble, such as halogens and H_2S, when water is condensed from the cooled LFG. Do not use systems containing chlorofluorocarbons refrigerants. Coordinate condenser LFG output quality and flow with any other LFG treatment technologies requirements that may be incorporated in the design, such as activated media. Provide a condensate drain and piping, as required by the equipment manufacturer, for condensate disposal.

6-3.4.3 Flare and Propane Feed.

Use a high temperature flare to combust the LFG when the processing plant is down or when a surplus of LFG is collected. Provide an oxygen content alarm to maintain safe flare operation and prevent oxygen intrusion into landfill and potential combustion. Select enclosed or candlestick flare based upon the approval authority requirements and project economics. Use flares that are self-supporting and designed for the wind and seismic conditions specific to the area where they will be installed. Comply with EPA Non-Methane Organic Compound Emission Guidelines.

6-3.4.4 Enclosed Flare.

The enclosed flare is preferred for methane and trace compounds combustion as these flares are considered more efficient at reduction of greenhouse gas emissions and typically provide more sensing and control options. The enclosed flare is also considered more visually pleasing as LFG combustion is not as noticeable as is with a candlestick flare.

6-3.4.5 Candlestick (Open) Flare.

Candlestick flares combust the waste gas at the flare top. Construct the flare of steel with a windbreaker and include a control outlet, flame arrestor, and propane ignition system. Use a flare with a shell comprised of steel and a refractory insulating material. Provide with flame arrestor, control valve, air damper and temperature and flame sensors, and controls. Consider using a purge blower to purge traces of LFG from the flare prior to ignition. Include a propane or natural gas pilot system. Design flare for a minimum retention time and temperature to allow for an effective and complete LFG combustion.

6-3.4.6 LFG Primary Treatment Plant.

Design the primary treatment plant to further process the LFG after the extraction plant and before use in electricity or heat generation. The treatment plant consists of equipment, aligned in series, for removing condensate, particulates, hydrogen sulfide, siloxanes, and halogenated compounds from LFG. Use economics evaluation and the desired fuel grade required for the end use to determine gas treatment requirements.

6-3.4.7 Facility.

Design the facility to ensure safe operation, a secure premises, proper maintenance space, and adequate separation of spaces to meet hazardous area classifications. Design the facility to have provisions for future expansion and installation of more equipment if expansion potential exists. Provide all buildings with gas monitoring probes to detect gas collecting around and underneath the building foundation.

At a minimum, construct a steel framed building with a roof and a concrete foundation. Design enclosed buildings, consisting of a roof, walls, and concrete foundation, as necessary to house the equipment type being utilized and support maintenance requirements. Separate electrical panels and equipment in enclosed buildings from any gas piping or other gas processing and conveying equipment. Provide a security fence surrounding the premises. Equip all enclosed buildings with an indoor air quality (IAQ) detection system with sensors, alarms, and interlocks to other safety devices and equipment such as mechanical ventilation and exhaust systems.

6-3.4.8 Components.

6-3.4.8.1 Blowers.

Add blowers, downstream from the extraction blowers, to increase the LFG pressure to overcome pressure losses in the treatment components.

6-3.4.8.2 After Cooler.

Use after coolers, following a blower, to lower the gas temperature as required by equipment downstream of the blower. Select after coolers to include a heat exchanger. Select an air cooled or refrigerant cooled machine based upon required equipment performance.

6-3.4.8.3 Pretreatment.

Pretreat or precondition the gas, prior to its end use, to prevent equipment inefficiencies, equipment damage, and frequent maintenance service.

6-3.4.8.4 Treatment Requirements.

Determine the expected final LFG fuel grade prior to selecting treatment equipment and technologies.

6-3.4.8.5 Treatment Technology.

Use treatment technologies that provide the proper conditioning and filtering required while requiring minimal maintenance and waste. Equipment utilizing a combination of technologies to remove multiple contaminants may be used.

6-3.4.8.6 Water Removal.

Use either refrigeration type technologies which employ heat exchangers, utilizing refrigerant or chilled water, or use a desiccant type system, which may use a silica type gel. A combination of systems may be employed to dry the air. Use a combination of condensate knockout tanks throughout the treatment system to further reduce the gas moisture content. Provide a condensate drain, as required by the equipment manufacturer, for condensate disposal.

6-3.4.8.7 Particulate Removal.

Use stainless steel mesh screens after the condensate knockout located in the LFG piping, and before the blower inlet. Use mesh screens to filter particles as small as 1.0 micron. Verify screens use are required prior to other treatment technologies and equipment, and select recommend micron size.

6-3.4.8.8 Foam Removal.

Use coalescing stainless steel mesh screens after the condensate knockout located in the LFG piping upstream of the blower. Provide a condensate drain, as required, for condensate disposal.

6-3.4.8.9 Siloxane Removal.

Use activated alumina, activated carbons, refrigeration type systems or a combination of these systems may be used to remove siloxane. The concentration range of siloxane after removal should be less than 100 parts per billion (ppb). Provide a condensate drain as required for condensate disposal.

6-3.4.8.10 Hydrogen Sulfide Removal.

Use an iron sponge to further reduce hydrogen sulfide. Provide a regeneration system as required by the equipment manufacturer. Provide a condensate drain, as required, for condensate disposal.

6-3.5 Condensate Collection and Treatment System in LFG Treatment Systems.

Treat collected condensate to local standards before final discharge.

6-3.5.1 Design Considerations.

Landfill gas typically contains water vapor. When the LFG is cooled, the water vapor in the gas stream will form droplets and the droplets combine to form condensate. The condensate quality from LFG depends on a number of factors from where the condensate originated. Condensate typically contains a number of volatile organic compounds (VOCs). The factors affecting the condensate quality are listed below:

- Waste type and nature;
- Age of waste;
- Climatic conditions;
- Moisture content within the landfill;
- Ambient temperatures and temperatures within the landfill;
- Landfill site configuration;
- Landfill overall size;
- Landfill covers and liners and their effectiveness; and
- Condensate production rate.

Estimate the condensate production rate by assuming the LFG is fully saturated and assuming that all the condensate will condense out of the LFG while it is cooled in the component cooling the gas. Size condensate piping for estimated condensate flow.

6-3.5.2 Condensate Piping.

The preferred condensate piping is HDPE type.

6-3.5.3 Condensate Pumps.

Use compressed air or electrical condensate pumps sized to accommodate the modeled condensate production rate.

6-3.5.4 Condensate Treatment System.

If allowed by local, State and Federal regulatory agency guidelines, drain generated condensate back into the landfill for processing. If the amount and / or characteristics of the condensate do not allow draining back into the landfill, determine and implement appropriate pretreatment measures before discharging into a local wastewater treatment system.

6-3.6 Power Generation Plant.

Internal combustion engines and gas turbines are the most common technologies for LFG energy generation. These technologies can be used individually or together maximizing the best and most efficient use of projected gas flow from the landfill over time.

6-3.6.1 Energy Conversion Technology.

Select the energy conversion technology based upon the developed electrical energy output as follows:

- 800 kilowatts (kW) to 3 megawatts (MW) – use internal combustion engines with multiple engines for 1 MW to 3 MW range unless gas turbines are determined to be the most effective / cost efficient;
- 5 MW or More – use gas turbine engines;
- Less than 250 kW – use microturbines.

6-3.7 Process Controls and Alarms.

Refer to EM 200-1-22 for landfill off-gas collection and treatment design requirements. Automated process controls are the preferred type. Provisions for the control points, at the minimum, must include:

- Flare and blower interlocks;
- Flare temperature;
- Pilot ignition status with blower operation sequence;
- Emergency fail-safe operation to isolate piping during power loss or outage;

- Pressure and flow measurements for each well;
- Pressure measurements for blower inlet and outlet;
- Thermal overload protection for blower motors;
- Vacuum relief valves or switches / blower shutdown;
- Facility IAQ monitoring/alarm (minimum of methane and hydrogen sulfide);
- Near surface emissions monitoring/alarm;
- Methane LEL monitoring and emergency shutdown;
- Condensate collection monitoring/alarm; and
- Power plant generation technology and switchgear status.

6-3.8 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

6-4 OPERATION AND MAINTENANCE.

6-4.1 Contract Based Operations and Maintenance.

Minimum plant O&M requirements for plant equipment and material are those necessary to meet warranty, compliance, and expected life expectancy requirements. Ensure that:

- All equipment O&M and warranty materials are collected and consolidated into a comprehensive O&M guide for review before plant operations start;
- O&M service contracts are in place to start after the warranty period and are based upon an operating life of 20 years;
- Contractor provides all plant operation and maintenance necessary for contract and environmental compliance; and
- Contractor compliance requirements include collecting and providing all recurring data collection and report generation necessary for permit(s) compliance.

See Appendix E for addition O&M guidance.

6-4.2 Safety.

Comply to applicable provisions in 29 CFR 1910 and 29 CFR 1925, American Conference of Governmental Industrial Hygienists Threshold Limit Values and Biological Exposure Indices, 40 CFR Part 60, Appendix A, and 40 CFR Part 63, Appendix A. and local/agency codes and requirements. Provide air monitoring for indoor air quality and outdoor ambient conditions. Provide near surface methane monitor to ensure proper plant extraction operations and take corrective actions if methane readings are more than 500 ppm above background.

6-4.2.1 Non-Performance.

Ensure non-performance and remedy clauses are in maintenance contract to address non-conformance. Ensure liquidated damages address loss of power generation revenue and mission impacts.

6-4.2.2 Warranties.

Specific component warranties will vary with manufacturer. Warranties are typically limited to repair or replace, at manufacturers' discretion, the defective components, or assemblies. Warranty limits may include causes for materials, supplies, and equipment not manufactured or supplied by the manufacturer, unauthorized repairs or modifications, Acts of God, and incidental or consequential damages.

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CHAPTER 7 DESIGN CRITERIA - GEOTHERMAL SYSTEMS

7-1 INTRODUCTION.

This chapter identifies typical applications and defines the data development requirements to establish design criteria for a geothermal power generation plant. Ground source heat pump technology is not consider utility level power generation technology and is not discussed in this UFC. Viable geothermal power production requires a geothermal resource with three attributes:

- Fluid – Water naturally existing in the geothermal reservoir is used to extract heat in quantities necessary to meet power production requirements;
- Heat – Earth's natural temperature which increases with depth. High grade resources vary based upon geographic locations. Geothermal power plants are 8-15% energy efficient, dictating using only higher quality geothermal resources; and
- Permeability – The working fluid's (water) ability to adequately move through the geothermal resource between the production and injection wells via natural or induced fractures.

7-1.1 Technology.

Select technology based on the available geothermal resource temperature and type – dry steam, wet steam, temperature, and technologies. Table 7-1 provides technology considerations for available geothermal resource. Geothermal plant economics is greatly affected by resource characteristics such as temperature, flow rate, and depth, drill rig availability, and plant cost.

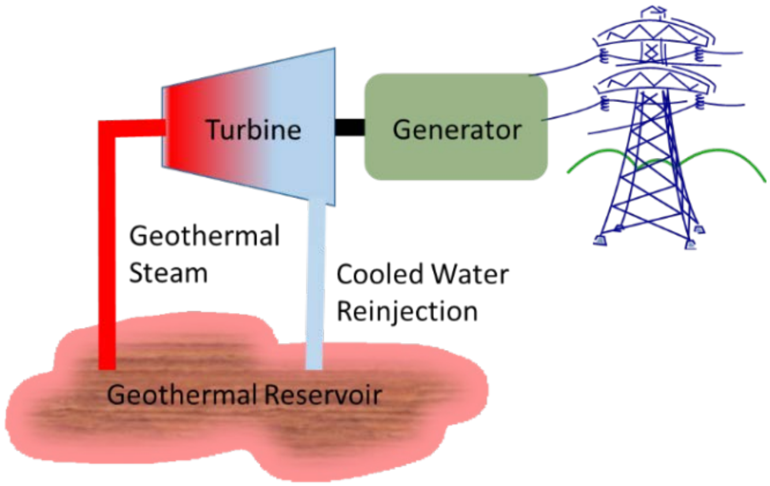
Table 7-1 Geothermal Resource Technologies

Resource Temperatures	Considerations for Use/Technologies
>400 °F (200°C) - High	Power generation – dry, flash, double flash, combination
300-400 °F (150-200°C) - Medium	Power generation – binary
<300°F (<150°C) - Low	Power generation – binary Direct use – processes, space heating, agriculture and aquaculture

7-1.1.1 Dry Steam Power Plants.

Use a dry steam power plant for a geothermal source producing high temperature steam, which does not contain water, to power the steam turbines. Inject spent geothermal fluid or low pressure steam back into the subsurface reservoir to continue the thermal cycle, as illustrated in Figure 7-1.

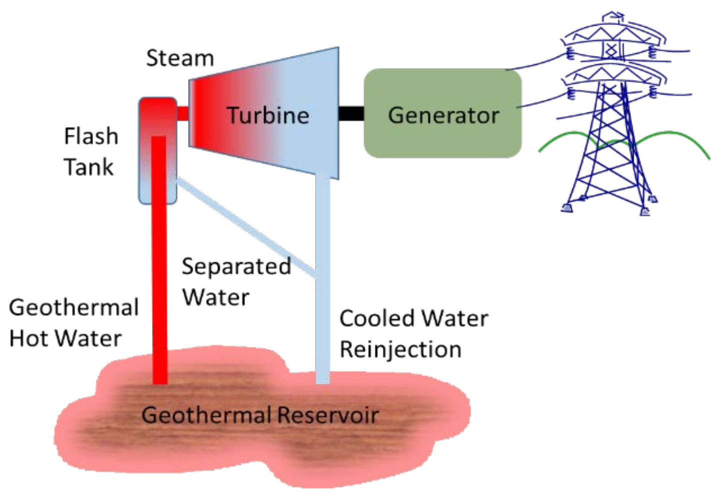
Figure 7-1 Dry Steam Power Plant



7-1.1.2 Flash Steam Power Plants.

Use a flash steam power plant when the geothermal source is high pressure hot water at the subsurface level. Design the system to flash high pressure / high temperature water into steam to power the turbines. Inject spent geothermal fluid or low pressure steam back into the subsurface reservoir to continue the thermal cycle, as illustrated in Figure 7-2. Evaluate binary generation economics using residual condensate.

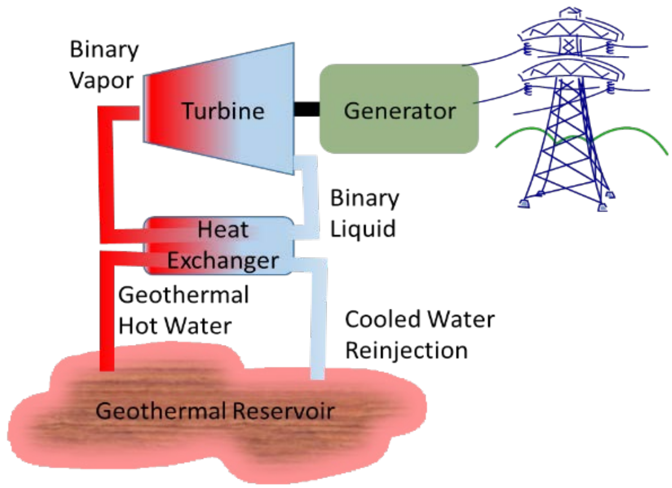
Figure 7-2 Flash Steam Power Plant



7-1.1.3 Binary Power Plants.

Use a binary power plant when the geothermal source has lower temperatures and in areas with sensitive environments. Design the binary power plant to have two separately piped, closed loop systems with pumps to move a working fluid and the geothermal fluid through a heat exchanger that will prevent the two fluids from coming into contact with one another. Select a working fluid that has a lower boiling point than water to allow it to vaporize into steam at lower temperatures. Inject spent geothermal fluid or low pressure steam back into the subsurface reservoir to continue the thermal cycle. Figure 7-3 illustrates Binary Power Plant.

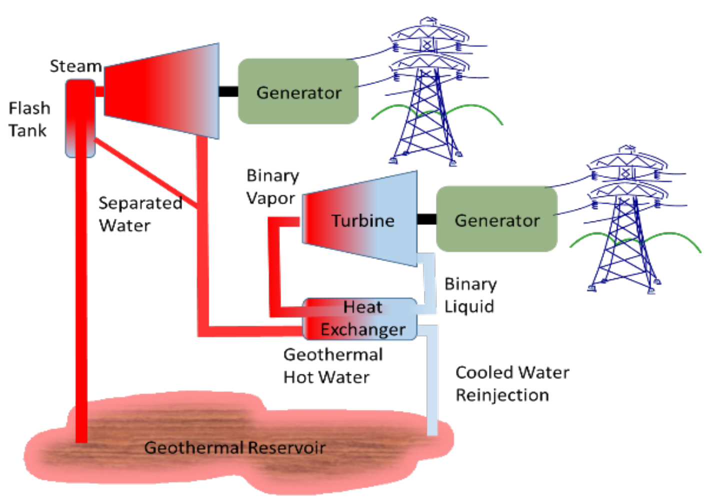
Figure 7-3 Binary Power Plant



7-1.1.4 Combination Flash and Binary Power Plants.

Use a combination flash and binary power plant when more than one geothermal source type is available at the location and sufficient residual thermal energy is available from the primary power cycle to economically use in a binary power plant. Figure 7-4 illustrates the application of a Combined Flash and Binary Power Plant.

Figure 7-4 Combination Flash and Binary Power Plants



7-1.1.5 Backpressure Plants.

Backpressure plants are not authorized. Back pressure plants discharge directly into the atmosphere and are less efficient than other plant types. Not re-injecting fluids limits the geothermal resource life and released fluids may have a chemical composition hazardous to the environment.

7-1.2 Geothermal Resource Types.

7-1.2.1 Conventional Hydrothermal.

Conventional hydrothermal resources are defined by level of development, and include:

- Conventional hydrothermal unproduced resource is a geothermal resource that has not been previously used;
- Conventional hydrothermal produced resource is a geothermal resource that has been previously used to support geothermal power plant(s); and
- Conventional hydrothermal expansion resource is an existing power plant and associated drilled areas.

7-1.2.2 Enhanced Geothermal.

Enhanced geothermal is a geothermal resource in sufficient temperature, but lacks water or permeability for sufficient geothermal fluid production for power production. Hydro-fracturing is used to create new and increase existing fractures to increase permeability in the geothermal reservoir. Surface or subsurface water is pumped through the more permeable geothermal reservoir to produce the necessary working fluid flow for power production in the power plants previously described for enhanced resource temperatures and pressures.

7-1.2.3 Other Geothermal Resources.

Other resource types include 1) geopressured system – high pressure water/gas reservoir which contain a gas (typically methane) and water/brine mix; and, 2) co-production – geothermal and hydrocarbon resource that uses high temperature fluids resulting from oil/gas field development.

7-1.2.4 Geopressured Systems.

Geopressured pilot plants utilizing the produced natural gas and the water's thermal energy have been proven viable. Plant technologies included natural gas fired engines and binary geothermal plants. Spent geopressured fluids may be re-injected or processed for potable water and brines.

7-1.2.5 Co-production.

Water by-product is typically re-injected into the production strata. Before re-injection, the water volume and temperature may be sufficient for used in a closed loop binary plant.

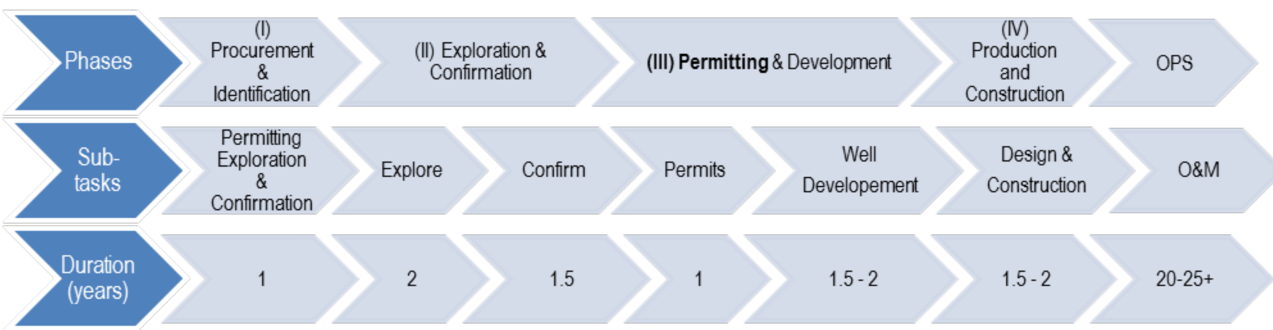
7-2 PLANNING.

32 CFR Part 211 requires DoD to conduct mission compatibility evaluation of proposed site and project. Early project awareness and coordination is mandatory. Request a preliminary siting determination from the OSD Clearing House at osd.dod-siting-clearinghouse@mail.mil. Refer to paragraph entitled "COORDINATIONS" in Chapter 2 for required submission information.

7-2.1 Project Development Phases.

Consider using the Geothermal Energy Association four phase geothermal power project development timeline, listed below, for project development. These phases are described further in paragraphs 7-2.3 through 7-2.6. Figure 7-5 provides estimated planning timelines, by phase. Actual timelines are location and capacity specific. Some tasks may occur concurrently. Total project development timeline is typically 4-7 years.

Figure 7-5 Geothermal Project Planning Timeline



7-2.2 Geothermal Terms and Definitions.

The Geothermal Energy Association provides terms and definitions, by phase, at http://geo-energy.org/pdf/NewGeothermalTermsandDefinitions_January2011.pdf.

7-2.3 Phase I Resource Procurement and Identification.

This phase results in a Possible Resource Estimate and Possible Installed Capacity Estimate for the geothermal resource and the power plant. Review available data to determine evidence of geothermal potential in the desired area and what issues may arise in a procuring a geothermal plant. Refer to paragraph titled "COORDINATIONS" in Chapter 2.

7-2.3.1 Geothermal Assessment.

The highest risk for geothermal power production is finding a viable geothermal reservoir. Due diligence during Phase I is critical to reducing risk. Review information and literature pertaining to geological, hydrological, hot spring, thermal data, drilling data, active remote sensing (LIDAR, radar), passive remote sensing (multispectral, thermal, hyperspectral alteration mineralogy), and anecdotal information from local personnel. The U.S. Geological Survey contains maps, geochemical analyses, and geothermal activity information that are valuable resources. New evaluation techniques are being developed to find and assess ‘blind’, i.e. no surface indications, geothermal resources.

Once the site is defined, and before drilling initial test holes, perform geoscientific surveys / studies such as geochemical, geological, magnetotellurics, and geophysical tests, to minimize exploratory drilling costs.

7-2.3.2 Location Restrictions.

Preform initial power transmission analysis (availability, access, and capacity) to determine viable avenues to transmit power to the electrical grid. Perform initial infrastructure capabilities and restrictions, e.g. roads, water, power, bridges, communications. Use UFC 3-201-01 to evaluate existing site conditions and site development requirements.

7-2.3.3 Environmental Concerns.

Evaluate water, site, and air permitting requirements applicable to geothermal plant type. Begin initial discussions with local and State environmental organizations and local water/aquifer districts. Geothermal power generation plants do no burn fuel; however, they can emit trace amounts of nitrogen oxides, almost no sulfur dioxide or particulate matter, small amounts of carbon dioxide, and sometimes hydrogen sulfide, which is naturally present in many geothermal reservoirs. Other pollutants, such as mercury, may be present in trace amounts. Geothermal waters can be dangerous to humans and surrounding ecosystems as they contain varying concentrations of potentially toxic minerals and elements, and are extremely hot. However, geothermal waters are typically re-injected into the geothermal reservoir and do not contact surface ecosystems or drinking/irrigation aquifers.

7-2.3.4 Scaling and Corrosion.

Mineral scaling on or corrosion of equipment and piping are major operational concerns. Boiling point scaling may consist of calcium carbonate and metal sulfides; and, calcium carbonate and amorphous silica in surface equipment and re-injection wells scaling. Corrosion may include sulfide stress cracking in well piping; sulfuric acid corrosion at wellheads; hydrochloric and carbonic acids corrosion in surface and condensate pipeline; and, stress corrosion cracking in exchangers.

As hydrogen sulfide (H_2S) corrodes copper into Cu_2S, ensure surface electrical wiring and electronics are protected against a H_2S atmosphere, if present. Control humidity using sealed containers, coatings, sealants on wires, electronics, and control equipment, and clean air ventilation to reduce H_2S induced copper corrosion.

7-2.3.5 Scale and Corrosion Testing Requirements.

Perform water testing and hydrogeochemical model to determine expected corrosion or scaling mineral composition, and implement applicable countering means and methods. Perform mineral composition analysis on any accumulated scale before system cleaning and disposal operations. Perform the following water sample measurements as a minimum: pH, SiO_2, Na, K, Ca, Mg, Cl, SO_4, HCO_3/CO_3, and key trace elements Li, Rb, Cs, B, F, Al and Fe.

If site has environmental concerns, include As and Hg measurements. Test for the following gas sample measurements as a minimum: CO2, H_2S, NH_3, N_2, CH_4, H_2, Ar and O_2.

7-2.3.6 Recharge and Cooling Water.

Evaluate plant cooling water requirements, available source(s) (fresh, geothermal, effluent), and for adequate cooling water during planning phase. Table 7-2 provides median water use. Consider secondary use of rejected heat, such as space heating and agriculture. Consider sewage effluent as a geothermal reservoir recharge option. High temperature (400 ^{0}F / 200 ^{0}C) environments sterilize any residual organic material and this alternate disposal method eliminates waterway discharges.

Table 7-2 Median Water Use

Cooling Type	Technology	Median gal/MWh (l/MWh)
Tower	Dry Steam	1,796 (6799)
	Flash (freshwater)	10 (38)
	Flash (geothermal fluid)	2,583 (9778)
	Binary	3,600 (13627)
	EGS	4,784 (18109)
Dry	Flash	0 (0)
	Binary	135 (511)
	EGS	850 (3218)
Hybrid	Binary	221 (836)
	EGS	1,406 (5322)

7-2.3.7 Visual and Sound.

Geothermal power plants have minimal visual and noise impact once construction is complete. Cooling tower steam plumes are the most likely visual item noted. A plant's mechanical equipment may produce undesirable noise levels unless sound attenuation is specified. Specify overall plant maximum sound pressure (ex. 85 decibels at 1 m from enclosure) based upon local codes. Do not specify individual equipment sound pressures as reverberations and reflections compound individual sound pressures and may exceed specified decibel limit. Comply with UFC 3-450-01.

7-2.3.8 Subsidence.

Geothermal condensate re-injection minimizes subsidence caused by power generation. Tectonically active areas have naturally occurring subsidence. Document these natural movements in the planning and permitting documentation and measure local subsidence a minimum of every five years.

7-2.3.9 Induced Seismic Activity.

Geothermal reservoirs are typically located in areas of natural tectonic activity. The process of enhancing geothermal resources and reinjection may induce or increase frequency of micro-tremors. These micro-tremors are rarely the magnitude for humans to feel and are not in any general sense problematic for life or property surrounding the plant. Public awareness and mitigation planning is required to ensure community concerns are fully addressed early in the project timeline.

Perform initial screening, community outreach, baseline criteria and seismic monitoring, event hazard analysis, risk decision analysis for plant design, and risk-based mitigation plan for operations. Refer to paragraph entitled “GEOTHERMAL POWER GENERATION” in Appendix B for additional details on the recommended seven step protocol. Install a micro-earthquake monitoring system before production drilling to establish a seismic baseline and to monitor earthquake activity during operations.

7-2.3.10 Resource Evaluation.

Determine geothermal resource legal ownership as resource likely extends outside of installation boundaries. Establish legal rights to the geothermal resource before developing.

7-2.3.11 Power Agreements.

Coordinate with the local utility(ies) and transmission services provider(s), as well as the agency / installation involved on viability of obtaining power purchase agreements (PPA) and interconnection agreements for the proposed plant.

7-2.3.12 Planning Capital Expenditure.

For initial planning purposes, use the average plant capital expenditures for plants completed from 2011 to 2013 – $2.65 million/MW for flash plants, and $5.18 million/MW for binary plants – and escalate to mid-point of expected construction. Update costs at each phase as project requirements are further refined.

7-2.3.13 Phase I Findings.

Use Phase I findings to create an outstanding issues cost / risk / benefit matrix to support a project go / no-go decision before proceeding to Phase II.

7-2.4 Phase II Resource Exploration and Confirmation.

This phase results in a refined Possible Resource Estimate and refined Possible Installed Capacity Estimate for the geothermal resource and the power plant. Once site is validated under Phase I assessment, determine if site resources meet power generation requirements, transmission capabilities, and site development criteria.

7-2.4.1 Permit Applications.

Generate and submit appropriate permits for approval to drill resource development wells described under resource development. Coordinate with State and local environmental offices and water resource organizations.

7-2.4.2 Resource Capacity Analysis.

At the potential sites developed under Phase I, drill wells to gather site specific thermal data to refine resource location and to develop the Phase II geothermal *Possible Resource Capacity*. Drilling may be accomplished in a multi-step process to reduce costs: 1) drilling of shallow holes across suspect area to determine viable thermal gradients; if viable area found, then, 2) drilling of a ‘slim hole’ to validate thermal gradient; if a viable gradient is found, 3) extending the slim hole to penetrate the reservoir; and if a viable reservoir is found, 4) re-drilling the slim hole to full diameter production well or drilling new production sized well.

7-2.4.3 Transmission Development.

Initiate detailed utility transmission and interconnect requirements analysis and feasibility studies with grid owners. Refer to Chapter 8 titled “UTILITY INTERCONNECTION” for guidance.

7-2.4.4 Phase II Findings.

Generate a *Possible Resource* capacity estimate and a *Possible Installed Capacity Estimate* specifically used for the financial evaluation for plant’s geothermal power production. Identify any initial potential project issues associated with local communities, transmission, sites, environmental, and any other applicable issue area.

Use Phase II findings create an outstanding issues cost/risk/benefit matrix to support a project go/no-go decision before proceeding to Phase III.

7-2.5 Phase III Permitting and Initial Development.

This phase results in a Delineated Resource Estimate and Delineated Installed Capacity Estimate for the geothermal resource and the power plant.

7-2.5.1 Permit Applications and Contracts.

Obtain applicable drill permit(s) for one full size production well. Start initial plant permit applications and Power Purchase Agreements (PPA). Developer to determine financing avenues to meet PPA requirements.

7-2.5.2 Resource Development.

The size and cost of a steam gathering system is affected by site topography, slope stability, steam field size and spread, and resource temperature and pressure. Locate production and injection well(s) to optimize reservoir recharge capacity. Injecting spent (cooled) geothermal liquid too close to a production well may locally cool the reservoir and subsequent production. Injecting spent geothermal liquid too far from the project well(s) may not sufficiently replenish the reservoir and steam pressure may decline.

Drill one full size production well with sufficient bottom hole temperature and flow rates for a commercial size geothermal well (3-5 MW gross equivalence). Drill one full size injection well capable of recharging the geothermal resource. Size production and injection well to allow the equivalent of at least 20% of proposed plant capacity. Use the production and injection well flow and thermal data to characterize the overall geothermal resource fluid flow and sustainable capacity.

7-2.5.3 Transmission Development.

Complete an interconnection feasibility Study and System Impact Study (SIS) to determine connection requirements. Request the utility to start the interconnection facility study to address the steps, equipment, and facilities required to connect to the grid. The developer shall submit the transmission service request to permit power transmission.

7-2.5.4 Phase III Findings.

Generate a *Delineated Resource Estimate* and a *Delineated Installed Capacity Estimate* specifically used to revise the Phase II financial evaluation for plant’s geothermal power production. Identify any additional potential project issues associated with local communities, transmission, sites, environmental, and possible resolutions.

Use Phase III findings create an outstanding issues cost / risk / benefit matrix to support a project go / no-go decision to proceed with project approval, contactor selection and award, and before proceeding to Phase IV activities.

7-2.6 Phase IV Resource Production and Power Plant Construction.

This phase results in a *Confirmed Resource Estimate* and *Confirmed Installed Capacity Estimate* for the geothermal resource and the power plant. At Phase IV, activities shift primarily to selected contactor activities.

7-2.6.1 Resource Development.

The selected contractor finalizes plant design; begins production well(s) development; and plant construction starts.

7-2.6.2 Transmission Development.

Complete interconnect requirements analysis and feasibility studies. Obtain signed interconnection agreement with utility.

7-2.6.3 Permitting and Contracts.

Finalize PPA terms and conditions; plant construction permits approvals, and contract to design-build power plant, remaining production wells, steam gathering system, transmission lines, and remaining infrastructure to initial final design and construction.

7-2.6.4 Phase IV Findings.

Generate a *Confirmed Resource Estimate* and a *Confirmed Installed Capacity Estimate* specifically used for the financial evaluation for plant's geothermal power production. Identify any additional potential project issues associated with local communities, transmission, sites, environmental, and possible resolutions.

7-3 DESIGN CRITERIA.

7-3.1 General Design Requirements.

Comply with UFC 1-200-01. Geothermal power plant designs typically include:

- Site civil engineering;
- Well development;
- Steam enhancement and cleaning;
- Turbines;
- Condensing, gas ejection and cooling systems;
- Distributed control systems (DCS);
- Piping, valves and power island blowout preventer (BOP);
- Electric power generation and plant support systems;
- Electrical cabling, substation, and high voltage power interconnection; and
- Supporting structures consisting of turbine/generation building, black start generation, emission monitoring, gatehouse and security spaces, administrative and maintenance spaces, and fire pump house.

7-3.1.1 Layout.

The facility is to be designed with the concept of providing efficient operations and maintenance activities throughout the facility life. The design process must include a general configuration of all proposed buildings and structures, piping runs, wellheads, roads, parking and paved areas, as well as drainage features and any associated retention basins during site development / construction, and long term operation stages. Layout site to minimize footprint while protecting equipment and electrical systems from steam vetting to reduce equipment corrosion. If cost effective, consider redundant systems to allow O&M actions while maintaining operations.

The facility roadway system design must provide a traffic pattern allowing simultaneous traffic to both enter and exit the facility, and allow unencumbered travel of vehicles in both directions throughout the facility.

7-3.1.2 Materials.

Geothermal fluids are corrosive. All materials used will be selected for durability and longevity for their respective environments and in compliance with local architectural standards. As a minimum, the facility structure will be of concrete or steel construction with factory finished coating system steel exterior wall surfaces or architectural masonry. Use metal roofing, sloped for drainage. Exterior personnel doors will be galvanized insulated core steel with window lights and security systems, where appropriate. Overhead doors will be galvanized steel. Windows will be insulated double pane glass with insulated aluminum jambs. Floor finishes will be selected based upon safety and use.

All open grate working platforms, open grate stairs, ladders, ladder cages, and handrails at the exterior are to be galvanized steel coated after fabrication. Where steel components are exposed to corrosive materials, use coating systems that are specifically resistant to the corrosive materials.

7-3.2 Well Development.

Geothermal well development is very similar to oil / gas well development. Use drillers licensed for the location and have experience with large diameter geothermal wells. Size well casings for function (conductor, surface, intermediate, production), flow, and working pressure. Use static seals with no external energizing. Ensure the design accommodates casing expansion without restricting flow. The design shall allow installation before the casing cementing process to allow for alignment and casing reciprocation during cementing. Provide blowout prevention and other safety equipment as required for hazard classification. See “GEOTHERMAL POWER GENERATION” in Appendix B for drilling and materials best practices.

Specify pipe according to well conditions, fluid chemistry, and depth. Wells will have multiple casing materials; for example, two separate, 3 mi (5 km) deep, enhanced geothermal EGS wells have the following material characteristics, as shown in Table 73.

Table 7-3 Example EGS Well Material Design

Well Depth (km/mi)	Casing Schedule	Material	Depth (m/ft.)	Casing Length (m/ft.)	Hole Diameter (cm/in)	Casing Diameter (cm/in)
EGS#1 5 / 3.1	Conductor Pipe	Welded wall	24 / 79	24 / 79	91.4 / 36	76.2 / 30
	Surface Casing	Welded wall	381 / 955	381 / 955	71.1 / 28	55.8 / 22
	Intermediate Liner	K-55 Premium	1524 / 5000	1204 / 3950	50.8 / 20	40.6 / 16
	Production Casing	T-95 Premium	3999 / 13120	3999 / 13120	37.4 / 15	29.8 / 12
	Production Slotted Liner	K-55 Buttress	4999 / 16400	1061 / 3480	26.3 / 10-1/2	21.9 / 8-5/8
EGS#2 5 / 3.1	Conductor Pipe	Welded wall	30 / 98	30 / 98	106.6 / 42	91.4 / 36
	Surface Casing	Welded wall	381 / 1250	381 / 1250	81.2 / 32	71.1 / 28
	Intermediate Liner #1	K-55 Premium	1524 / 5000	1204 / 3950	66.0 / 26	55.8 / 22
	Intermediate Liner #2	K-55 Premium	3048 / 10000	1280 / 4200	50.8 / 20	40.6 / 16
	Production Casing	T-95 Premium	3999 / 13120	3999 / 13120	36.2 / 14-1/4	29.8 / 12
	Production Slotted Liner	K-55 Buttress	4999 / 16400	1061 / 3480	23.0 / 9	21.9 / 8-5/8

7-3.3 Steam Enhancement and Cleaning.

Evaluate geothermal fluid chemical characteristics and select equipment materials tailored to reduce corrosion characteristics. Evaluate and account for non-condensable gases (NCG) removal, such as hydrogen sulfide (H_2S) and carbon dioxide (CO_2). NCG reduces plant efficiencies due to equipment parasitic loads and NCG accumulation in the condenser leads to a higher turbine outlet pressure and a lower power output per unit of steam.

Use centrifugal or cyclone type steam separator designed for site specific geothermal fluids. Evaluate separator location to optimize plant performance and life cycle costs. Locations include adjacent to wells to reduce two phase liquid piping losses between the well and turbine, or near the turbines to reduce piping losses and allowing more brine to flash to steam.

7-3.4 Turbines.

Select turbines with materials specifically designed for site specific geothermal fluid, and to minimize and protect against dissolved gases, impurities, and water droplets corrosive effects.

7-3.4.1 Materials.

Require corrosion resistance treatment, such as Stellite alloy and induction treatment, to increase blade and turbine life.

7-3.4.2 Condensate Removal.

Require turbines have excessive condensate removal systems to reduce water droplet erosion.

7-3.4.3 Valves.

Require fast closing inlet valves for system emergency shutdown. Require low fouling or scaling valves to reduce potential closure failures.

7-3.4.4 Seals.

Evaluate and select shaft seals designed for simplicity, long life, and maintainability.

7-3.5 Condensing, Gas Ejection and Cooling Systems.

Use vacuum pump systems to extract NCG from the condenser to maintain condenser efficiency. Design H_2S systems to comply with location specific environmental, health and safety requirements and laws. Ensure sufficient contingency capacity is included in NCG systems. The amount and type of H_2S abatement required varies considerably and is dependent upon the reservoir characteristics. NCG concentration and the corresponding H_2S concentration may vary dramatically from reservoir to reservoir and from well to well within the same reservoir. H_2S removal systems include exhausting, thermal oxidation to covert to sulfur dioxide (SO_2), and solid (example iron) and liquid scavengers. Evaluate and select environmentally viable removal systems, including consumables and disposal costs, for best life cycle cost.

Evaluate air or water cooling / condensing system based upon environmental considerations, resource availability, and life cycle costs. Water-based cooling systems have higher heat transfer rates than dry air. Water based systems include direct contact condensers where both the cooling water and steam are combined and sprayed in the condenser; once through condensers using surface water source; and wet cooling towers. Dry type cooling towers have significantly less thermal rejection efficiency and water based systems. Use of dry type cooling towers will increase project costs by 10-20%, but may be only solution for sites with inadequate water supplies, strict water use regulations, or extremely low ambient conditions which causes water tower drift to freeze on surrounding surfaces and plants. Ensure the safety control and valve system prevents condenser backflow into the turbine.

7-3.5.1 Piping, Valves and Blowout Preventer.

Piping system designs must be robust to handle brine, two-phase liquids, steam, and entranced debris. Accommodate thermal expansion, condensate collection and disposal, slug flow, erosion from and elimination of entrained debris, and elevation induced pressure issues. Evaluate life cycle cost between use of corrosion resistant materials (stainless/alloys) or corrosion resistive coatings on lower cost carbon steel.

7-3.5.1.1 Two-Phase Fluids.

Minimize two-phase piping lengths to reduce pressure losses. Upslope two-phase piping design is not allowed as it encourages slugging. Evaluate brine line saturation pressure to ensure the brine will not flash into steam and create two-phase conditions.

7-3.5.1.2 Insulation.

Insulate piping to reduce thermal gradient and energy loss between the piped geothermal fluids and the ambient air.

7-3.5.1.3 Pipe Loading.

Evaluate gravity loads for piping on long slopes. Analysis of areas near support anchors is especially important to ensure pipe design strength is sufficient to resist buckling.

7-3.5.1.4 Valves.

Select valve for specific service (e.g. steam, brine, water). Valve designed to minimize seal and operations issues from deposits. Provide seats with upstream and downstream metal-to-metal seals. Provide adjustable packing glands. Provide an overpressure rupture disk, or similar, for over pressurization protection. Free passage design for minimum pressure drop and turbulence. Select body material and overlays, such as Stellite alloy, for corrosion protection.

7-3.5.1.5 Blowout Preventer.

Provide either an annular or a ram type blowout preventer, with accumulator operating system, selected for pipe size and pressure rating in accordance with State and Federal regulations.

7-3.5.1.6 Standards.

Comply with ASME B31.1, ASME B31.3, API Spec 6A and ANSI B16.34.

7-3.6 Pumps.

Select pumps for specific service: e.g. steam, brine, temperature, flow, and pressure.

7-3.7 Heat Exchangers.

Evaluate preheater and vaporizer heat exchanger layout for increased efficiency on binary plants. Select material for specific service conditions and working fluids.

7-3.8 Working Fluids (Organic Motive Fluids).

For binary plants, select organic motive fluid formulations to cost effectively maximize the plant power output for site specific thermodynamic characteristics.

7-3.9 Distributed Control System (DCS).

Install a Distributed Control System consisting of an open standards software with programmable logic controllers for expandability, self-diagnostics, and backup modules. Include data points monitoring flows, pressures and temperature changes, vibration, fluid levels, control valves status, and equipment status. Minimum human interface requirements include plant systems diagrams, trend graphs, control loop diagrams, alarm events with time stamping for fault analysis, and logic monitoring. H_2S corrodes copper; ensure mounted control component are sealed (NEMA 4X). Ensure sensors contacting geothermal fluid are stainless steel rated for the fluid’s chemistry.

No direct communications with any DoD installation network is allowed unless system is certified through the DoD Information Assurance Certification and Accreditation Process and receive an Approval to Operate certificate. All Internet Connection Sharing (ICS) networks must be certified and have approval to operate regardless if they are connected the DoD NIPR network or not.

7-3.10 Electrical Systems.

7-3.10.1 General.

The electrical system for the plant will be a unit type system with the utility transformers connected solidly to the generator bus and switched with the generator.

7-3.10.2 Utility Interconnect.

Comply with the requirements of Chapter 8 of this UFC.

7-3.10.3 Generator.

Provide totally enclosed, synchronous generator sized for continuous operation directly connected to steam turbine. Generators up to 60 MW are to be air cooled. Coordinate output characteristics with ITO/RTO and local utility. Comply with UFC 3-540-01.

7-3.10.4 Synchronizing Switchgear.

Provide a substation on the facility site of a modern, fenced, low-profile design, and complete with bus duct connection between generator switchgear and facility step-up transformer. All the electrical equipment is to be protected from electrical fault damage by protective relays. The substation is to operate over the range from import of full station auxiliary power requirement to export of full net plant real and reactive power capability to the transmission system while maintaining standard operating voltage limits on the facility buses.

7-3.10.5 Plant Electrical System.

Provide a complete electrical system of medium-voltage, low-voltage, and DC power to all loads in the power plant under all service conditions including start-up, operation, failures, and shutdown. Provide unit substations with parallel step down transformers between the medium voltage and low voltage systems.

7-3.10.6 Plant Critical Loads.

Plant critical loads to operate off the low system include:

- Fire Pumps;
- Fire Jockey Pumps;
- Uninterruptable Power Supply(ies);
- DC Power System and Battery Chargers;
- Cooling Water Pumps;
- Hydraulic Pumps;
- Critical Lubrication Systems;
- Elevators; and
- Emergency Lighting.

7-3.10.7 DC System.

Provide a DC power system, with UPS, to provide for an orderly facility shutdown in the event of a loss of normal power. The DC power is to conform to the requirements of UFC 3-520-05.

7-3.10.8 Emergency Power System.

Provide an emergency power system for operating the plant critical loads in the event of a loss of normal power.

7-3.10.8.1 Uninterruptable Power Supply (UPS).

Provide a UPS system for the following critical loads:

- Fire alarm system;
- Mass notification system;
- Telecommunications system;
- Security systems;
- Plant distributed control system; and
- Critical instrumentation.

7-3.10.8.2 Generator.

Provide natural or diesel gas generator(s) if natural gas is not available, sized to handle the plant critical loads and an N+1 redundancy.

7-3.10.8.3 Transfer Switches.

Use automatic, bypass/isolation, overlapping neutral type transfer switches.

7-3.10.8.4 Fuel Storage.

If using diesel gas generator(s), provide a minimum fuel storage for operating at full emergency power for 5 days.

7-3.10.9 Lighting.

Lighting is to conform to UFC 3-530-01 and NECA/IESNA 502-2006.

7-3.10.10 Grounding/Lightning Protection System.

Grounding and lightning protection systems are to conform the following: IEEE C2, IEEE 142, NFPA 70, NFPA 780, and UFC 3-575-01.

7-3.10.11 Communications and Signal Systems.

Comply with UFC 3-580-01.

7-3.11 Project Planning Considerations.

Appendix D provides listing of factors to consider during the design. Tailor as appropriate for project scope.

7-4 COMMISSIONING.

7-4.1 Commissioning.

Create and execute a commissioning plan for geothermal and supporting systems in accordance with manufacturer's recommendations. Demonstrate all routine and emergency operations, and start-up and recovery actions. Include the following systems/sub-components in the commissioning plan, as a minimum:

- Supply/Return: blowout preventer, pumps, valves, meters and controls, and emergency shutdown;
- Plant: heat exchanger, turbine, generator, condenser, NCG scrubber, cooling tower, water storage, water treatment, pumps, valves, meters and controls, and emergency shutdown; and
- Transmission: transformer, switches, meters, and controls.

7-4.2 Measurement and Verification (M&V).

Develop and execute a M&V plan to evaluate plant performance throughout the life of the plant. Include the following systems/sub-components in the M&V plan, as a minimum, to verify plant and subsystems are operating within design parameters:

- Supply and injection;
- Plant heat exchanger, turbine, generator, cooling tower, condenser; and
- Electrical transmission.

Ensure M&V report provides summary analysis showing design flows, operating parameters, energy production verses design model (guaranteed production); actions taken to correct findings, and future improvement recommendations.

7-4.2.1 First Year.

Complete a full M&V during plant startup and at the end of the first full year after the plant reaches full operational capability, but no later than the end of the warranty period to identify and document production / warranty issues. Review results verses stated objectives and take appropriate actions to resolve unsatisfactory conditions. Perform system components baseline measurements and verify against plant design and component operating parameters. Perform mass and energy analysis to verify modeled performance verses actual flows and energy production.

Ensure the M&V report provides summary analysis showing design flows, operating parameters, energy production verses design model (guaranteed production), actions taken to correct findings, and future improvement recommendations.

7-4.2.2 Annual Measurement and Verification.

Review previous M&V reports and perform an annual M&V to evaluate plant performance and trends verses model and contract requirements. Identify trends and areas of concern, generate corrective actions, and create / update future improvement plant recommendations.

7-5 OPERATIONS AND MAINTENANCE.

7-5.1 Operations and Maintenance.

Minimum plant O&M requirements for plant equipment and material are those necessary to meet warranty and life expectancy requirements. Ensure all equipment O&M and warranty materials are collected and consolidated into a comprehensive O&M guide for review before plant operations start. Ensure plant operations procedures include compliance requirements for data collection and report generation, e.g. injection reports, production reports, blowout preventer inspections, annual water resource management plan updates, and monitoring and preventive actions to address corrosion and scaling concerns.

7-5.2 Contract Based Operations and Maintenance.

In contractor owned / operated enterprises, payments are based upon power delivered ($/megawatt-hour). Plant operations to meet all applicable local, State, and Federal operating permits. Ensure the Contractor provides all plant operation and maintenance necessary for contract compliance; and the Contract requirements include collecting recurring data and report generation necessary for permit(s) compliance, e.g. injection reports, production reports, blowout preventer inspections, annual water resource management plan updates, and monitoring and preventive actions to address corrosion and scaling concerns.

7-5.3 Safety.

Comply to applicable provisions in 29 CFR 1910, 29 CFR 1925, and 29 CFR 1926, and local/agency codes and requirements.

7-5.3.1 Non-Performance.

Ensure non-performance and remedy clauses are in maintenance contract to address non-conformance. Ensure liquidated damages address loss of power generation revenue and mission impacts.

7-5.3.2 Warranties.

Specific component warranties will vary with manufacturer. Warranties are typically limited to repair or replace, at manufacturers’ discretion, the defective components, or assemblies. Warranty limits may include causes for materials, supplies, and equipment not manufactured or supplied by the manufacturer, unauthorized repairs or modifications, Acts of God, and incidental or consequential damages.

CHAPTER 8 UTILITY INTERCONNECTION

8-1 INTRODUCTION.

This chapter provides the requirements and general procedures for utility interconnection as well as describes processes for plant performance.

8-1.1 Federal Energy Regulatory Commission (FERC) Rules.

Comply with the applicable FERC rule / standard when connecting a generator to a transmission system. Coordinate with local transmission and interconnection services provider for specific procedures in accordance with the provider's pro forma Open Access Transmission Tariff.

8-1.1.1 Standardization of Generator Interconnection Agreements and Procedures.

This encompasses interconnections greater than 20 MW. For additional information, the latest issue of Order No. 2003 can be referenced herein: http://www.ferc.gov/industries/electric/indus-act/gi/stnd-gen.asp

8-1.1.2 Standardization of Small Generation Interconnection Agreements and Procedures.

This encompasses interconnections of 20 MW or less. For additional information, the latest issue of Order No. 2006 can be referenced herein: http://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp

8-1.2 Non-FERC Standards.

Refer to the Interstate Renewable Energy Council's (IREC) interconnection standard for specific Level 4 procedures not subject to FERC. Comply with utility company current standards.

Comply with all the requirements of IEEE Std 1547. This standard addresses the interconnection technical and testing requirements necessary for electrical systems to operate under normal conditions without degradation. Prior to interconnection, provide proper documentation and certifications detailing all generation equipment, installation, operation, and maintenance compliance with IEEE Std 1547.

8-2 INTERCONNECTION REQUEST.

Contact the local transmission and interconnection services provider for the specific process to request interconnecting with the utility. The form requests information, such as project size, proposed point of interconnection, technical data and evidence of site control. A monetary deposit is usually associated with application request.

8-3 SYSTEM STUDY REQUIREMENTS.

After the initial interconnection request is submitted, it is appropriate for the transmission provider to perform a series of studies to ensure electrical power system safety and reliability by performing a feasibility study, system impact study, and facility study. Refer to IEEE Std 1547 for guidance on studies required based upon distributed generation and utility grid feeder characteristics.

8-3.1 Feasibility Study.

The feasibility study and scope will be based upon information set forth in interconnection request to transmission provider. The purpose of this study is to identify potential undesirable system impacts resulting from interconnection before additional studies are performed.

8-3.2 System Impact Study.

If any impact is identified from the feasibility study, a system impact study is then performed. The purpose of this study is to assess the impact of interconnection on the electrical system reliability, without any modifications.

8-3.2.1 Existing Infrastructure.

Maximize the use of existing infrastructure where appropriate in order to help minimize environmental and cultural impacts.

8-3.2.2 Planned System Modifications.

Consult the utility provider for any associated fees or additional studies required for planned system modifications needed for interconnection.

8-3.2.3 Load Flow Analysis.

Determine if the existing transmission facility is adequate to carry the additional generation reliably.

8-3.2.4 System Protection.

Refer to utility provider for specific requirements on types and models of equipment to ensure the proper operation, equipment compatibility, and stability of system.

8-3.2.5 Communications.

Consult with the utility provider for requirements of voice and data communications required for monitoring, recording, and transferring essential data.

8-3.2.6 Metering.

Refer to utility provider for functional specifications and design for the metering equipment. Comply with the local utility company's metering requirements as well as the OUSD (AT&L) Utilities Metering Policy as detailed in the following website http://www.acq.osd.mil/eie/IE/FEP_Policy_Program_Guidance.html and DoDI 4170-11 Installation Energy Management.

8-3.2.7 Other Considerations.

In addition to utility provider specific considerations, consider system upgrade costs, system security, contingency, and generation type.

8-3.3 Facility Study.

The facility study is performed to determine specific equipment and necessary modifications required to complete the interconnection. Also, associated costs and schedule for installation or upgrades are developed.

8-4 CONNECTION OPTIONS.

The generation facility's physical connection to the utility provider's transmission system can be accomplished by one of two types: station type or line type connection. The particular connection type will be determined by installation's location within the transmission system. Select the connection type using life cycle cost analysis and discussions with utility provider. Once the connection typed is determined, the generation facility can constructed to operate in parallel with the utility provider or as a detached system.

8-4.1 Station Type Connection.

In a station type connection, the generation facility is connected to an existing substation with direct lines and circuit breakers. Proper design and coordination is necessary in determining amount of lines and corresponding circuit breakers. Comply with specific utility provider guidelines for connection design.

8-4.2 Line Type Connection.

In a line type connection, the generation facility is connected to an existing transmission line with new transmission lines and a new switching station. Comply with specific utility provider guidelines on switching station configuration and design.

8-4.3 Parallel / Non-Parallel Connection.

In parallel connection, the generation equipment is connected to the utility's system bus and is operating in parallel with the utility's electric system. Comply with specific utility provider guidelines on parallel generation connection accommodations.

In non-parallel connection, there is no simultaneous connection between the generation equipment and the utility's electric system. Use a transfer switching arrangement to allow load shifting between the two systems in an open, or non-parallel, mode.

8-5 DESIGN REQUIREMENTS AND CONSIDERATIONS.

The following requirements and considerations apply to parallel operation and synchronization to the transmission system.

8-5.1 Voltage Requirements.

Design generation equipment to operate within the utility provider's established threshold.

8-5.2 Power Factor Requirements.

Coordinate with the utility provider on specific lagging/leading power factor ranges required at the interconnection point. If required by utility provider, consideration of supplying reactive power must be taken when in parallel connection to maintain desired power factor range.

8-5.3 Power Quality Requirements.

Comply with the following power quality requirements.

8-5.3.1 Voltage Flicker.

Generation equipment is not to cause voltage flicker exceeding the term limits specified in IEEE Std 1453.

8-5.3.2 Harmonic Distortion.

Comply with harmonic limits specified in the most recent revision of IEEE Std 519.

8-5.3.3 Communication Interference.

The total communication interference not to exceed the levels specified in IEEE Std 519.

8-5.4 Frequency Requirements.

When connecting to the utility, frequency deviations may be expected and can effect an entire interconnection. The system operating frequency to operate at the utility provider system nominal frequency range.

8-5.5 Abnormal Frequency Operation.

Provide frequency sensing equipment required to protect all generation equipment and facility during abnormal frequency operation.

8-5.6 Generator Step Up (GSU) Transformer Configuration.

Comply with the utility provider's specific protection, metering and operating requirements for parallel generation.

8-5.7 Induction Generator Unique Requirements.

Installing capacitors for reactive power supply at or near an induction generator can significantly increase self-excitation. During planning and design, verify the need by a system analysis. Refer to TSWEG TP-2 for additional information if power factor correction is considered.

8-5.7.1 Low Voltage Ride Through (LVRT) and Low Frequency Ride Through (LFRT).

Comply with IEEE Standard 1547. Voltage and frequency stability analysis studies system oscillations and is required when adding distributed generation into a system. Stable voltage and frequencies are primary concerns for transmission systems; therefore, this study must be performed prior to design completion because modifications of the proposed system may be required. The drop in voltage caused by reactive power deficiencies in the system are a severe concern. Generator rotor angle instability is also a cause of voltage instability. The most extreme instability is complete voltage collapse. Sudden changes in generation or load may result in system frequencies deviating from their normal ranges.

LVRT and LFRT Analysis involve the study of a distributed generation system's ability to continue after faults or disturbances in the system require wind turbines, PV systems, or small generators to drop off the system. Some generators use electricity to generate a magnetic field in order to function. If the voltage drops, these generators will drop off line. Synchronous machines will slip their frequency if the stator voltage drops significantly. If additional generation or load trips due to voltage or frequency disturbance, it has a potential to amplify the disturbance when more and more units rapidly fall off the line. This analysis determines which units will drop off, and if they will remain off or automatically restart. If the analyses show an issue, an engineered solution has to be designed to dampen or modulate voltage / frequency disturbances. Design renewable generation plants with LVRT and LFRT capability and adhere to applicable ISO / RTO standards or criteria. Coordinate with the utility provider in determining required clearing times.

8-5.8 System Grounding.

Comply with the requirements of IEEE Std 142.

8-5.9 Transient Stability.

Coordinate with the utility provider for specific criteria related to generator transient stability performance.

8-5.10 Excitation Control.

The excitation control system response ratio to conform to the latest edition requirements of ANSI Standard C50.13. Conform to applicable utility provider requirements.

8-5.11 Speed Governing.

Comply with the requirements of UFC 3-540-01 for generator speed governing systems.

8-5.12 Automatic Generation Control.

Coordinate with the utility provider for specific guidance and provisions.

8-5.13 Black Start Capability.

Depending upon the geographic location and other considerations, the utility provider may request generator black start capability in the event of a blackout. Coordinate with the utility provider for black start requirements.

8-5.14 Sub-Synchronous Torsional Interactions or Resonance.

Conform to the utility provider guidance and appropriate controls to eliminate damaging torsional oscillations resulting from voltage variations.

8-5.15 Metering.

All utility metering equipment shall conform to IEEE Std 1547. Refer to utility provider for specific metering, SCADA and communications requirements. Coordinate with the Base Operating Support (BOS) group for specific activity requirements or preferences and obtain approval from the AHJ for communication systems that enable remote access.

8-5.16 Transmission Line Design.

Transmission line design shall conform to the requirements in UFC 3-550-01. Determine the interconnection point and construct new transmission lines in accordance with utility provider criteria.

8-5.17 Protective Devices and Coordination.

All utility grade protective devices to conform to ANSI/IEEE Std C37.90. Prior to implementation, obtain utility provider approval for the selective coordination of overcurrent protective devices. Refer to IEEE Std 242 for guidance concerning coordinated power system protection.

8-5.17.1 Special Considerations.

Discuss with and determine the utility provider's specific protective devices specifications and installation requirements. Ensure protective relays are able to sense ground faults and automatic reclosing protection conforms to IEEE Std C37.60. Coordinate specific transformer zero sequence impedance requirements and generator under-frequency protection with NERC mandated automatic load shedding protection settings.

8-6 SUBSTATION EQUIPMENT.

Refer to IEEE Std 1613 for specific regulations governing the installation of substation equipment. If substation is utility-owned, obtain pertinent design information of utility-owned equipment to facilitate requirements for downstream equipment.

8-7 SCADA REQUIREMENTS.

8-7.1 General Requirements.

Refer to 18 CFR Part 35 and utility provider for general SCADA requirements and procedures. In addition, refer to applicable DoD directives concerning information assurance requirements for intelligence community (IC) systems. SCADA is to be equipped to monitor and report the location of a fault in any panel in a solar PV system.

8-7.1.1 Hardware.

Refer to utility provider guidance on approved interface equipment, communication, and hardware requirements for remote terminal unit (RTU) installations.

8-7.1.2 Revenue Metering Data.

Coordinate revenue metering requirements with the utility provider regarding interconnection-specific data.

8-7.2 Data Requirements.

Coordinate with the utility provider on determination of data and control points assignment / list and requirements. The RTU contains input/output functions to handle analog and digital data.

8-7.3 Supervisory Control Requirements.

Coordinate with the utility provider on requirements regarding supervisory control capability and responsibility.

8-8 TRANSMISSION OPERATIONAL REQUIREMENTS.

Coordinate the transmission operational requirements with utility provider based upon NERC and applicable RTO / ISO reliability standards. These requirements will be factors for interconnection including, but not limited to, in-service coordination, NERC registration, normal operating voltage schedule, and planned outage schedule.

APPENDIX A REFERENCES

A-1 FEDERAL

http://www.archives.gov/federal-register/

10 USC Part 2667, Leases: Non-Excess Property of Military Departments and Defense Agencies

10 CFR Part 436, Federal Energy Management and Planning Programs

18 CFR Part 35, Interconnection for Wind Energy

29 CFR 1910 Occupational Safety and Health Standards

29 CFR 1910 Subpart D, Walking Working Surfaces

29 CFR 1910 Subpart I, Personal Protective Equipment

29 CFR 1910.269(g), Fall Protection for Power Generation Industry

29 CFR 1925 Safety and Health Standards for Federal Service Contracts

29 CFR 1926 Safety and Health Regulations for Construction

29 CFR 1926 Subpart E, Personal Protective and Life Saving Equipment

29 CFR 1926 Subpart M, Fall Protection

32 CFR Part 211, Mission Compatibility Evaluation Process

40 CFR Part 60, Standards of Performance for New Stationary Sources

40 CFR Part 60.51c, Definitions

40 CFR Part 61, National Emissions Standards for Hazardous Air Pollutants

40 CFR Part 70, State Operating Permit Programs

40 CFR Part 71, Federal Operating Permit Programs

40 CFR Part 77, Excess Emissions

40 CFR Part 81, Designation of Areas for Air Quality Planning Purposes

40 CFR Part 257, Criteria for Classification of Solid Waste Disposal Facilities and Practices

40 CFR Part 266-273, Standards for the Management of Specific Hazardous Wastes and Specific Types of Hazardous Waste Management Facilities - Standards for

Universal Waste Management

49 USC Part 44718, Structures Interfering with Air Commerce

50 CFR Part 13, General Permit Procedures

50 CFR Part 17, Endangered and Threatened Wildlife and Plants

E.O. 13327, Federal Real Property Asset Management

FEDERAL AVIATION ADMINISTRATION

http://www.faa.gov/

FAA AC 70/7460-1K, Obstruction Marking and Lighting

FAA Form 7460-1, Notice of Proposed Construction or Alteration

National Oceanographic and Atmospheric Administration (NOAA)

https://www.ncdc.noaa.gov/data-access/severe-weather

Severe Weather Data

NATIONAL RENEWABLE ENERGY LABORATORY

http://www.nrel.gov/analysis/tech_size.html

Land Use by System Technology

http://www.nrel.gov/docs/fy15osti/62566.pdf;

Making Sustainable Energy Choices

http://www.nrel.gov/analysis/tech_footprint.html

Useful Life

http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html

Distributed Generation Renewable Energy Estimate of Costs

http://www.nrel.gov/docs/fy13osti/56266.pdf

Land Based Wind Turbine Systems Installed Capital Costs

U.S. ENVIRONMENTAL PROTECTION AGENCY

http://cfpub.epa.gov/ols/catalog/catalog_lookup.cfm

EPA-600/R-05/047, Landfill Gas Emissions Model (LandGEM) Version 3.02 User's Guide

EPA TO 14a, Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Specially Prepared Canisters with Subsequent Analysis by Gas Chromatography

LFG Energy Project Development Handbook

https://www3.epa.gov/lmop/publications-tools/handbook.html

U.S. DEPARTMENT OF ENERGY

http://apps2.eere.energy.gov/wind/windexchange/what_is_wind.asp

WINDExchange

http://apps2.eere.energy.gov/wind/windexchange/wind_maps.asp

Utility-Scale Land-Based 80-Meter Wind Maps

U.S. ENERGY INFORMATION ADMINISTATON

http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b

Table 6.7.B. Capacity Factors for Utility Scale Generators Not Primarily Using Fossil Fuels, January 2013-August 2015

http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015

A-2 DEPARTMENT OF DEFENSE

AIR FORCE

http://www.e-publishing.af.mil/

AFI 32-7006, Environmental Program in Foreign Countries

ARMY

http://armypubs.army.mil/epubs

USACE EM 200-1-22, Environmental Quality, Landfill Gas Collection and Treatment Systems

USACE ETL 1110-3-412, Engineering and Design: Transformer Application Guidance

USACE EM 200-1-22, Landfill Gas Collection and Treatment Systems

USACE EM 1110-1-1804, Geotechnical Investigations

USACE EM 1110-1-4016, Landfill Off-Gas Collection and Treatment Systems

DEPARTMENT OF DEFENSE (DOD)

http://www.defense.gov/resources/

DoDI 4170.11, Installation Energy Management

DoDI 4270.5, Military Construction

DoDI 7041.3, Economic Analysis for Decision Making

DoDI 8500.01, Cybersecurity

DoDI 8510.01, Risk Management Framework for DoD Information Technology

JOINT SERVICE

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, DoD Building Code (General Building Requirements)

UFC 3-201-01, Civil Engineering

UFC 3-230-02, Operation and Maintenance: Water Supply Systems

UFC 3-240-05A, Solid Waste Incineration

UFC 3-240-10A, Sanitary Landfill

UFC 3-260-01, Airfield and Heliport Planning and Design

UFC 3-301-01, Structural Engineering

UFC 3-400-02, Design: Engineering Weather Data

UFC 3-401-01, Mechanical Engineering

UFC 3-410-01, Heating, Ventilating, and Air Conditioning Systems

UFC 3-410-04N, Industrial Ventilation

UFC 3-420-01, Plumbing Systems

UFC 3-430-02FA, Central Steam Boiler Plants

UFC 3-430-03, Air Pollution Control Systems for Boiler and Incinerators

UFC 3-440-01, Facility-Scale Renewable Energy Systems

UFC 3-440-05N, Tropical Engineering

UFC 3-450-01, Noise and Vibration Control

UFC 3-501-01, Electrical Engineering

UFC 3-510-01, Foreign Voltages and Frequencies Guide

UFC 3-520-01, Interior Electrical Systems

UFC 3-520-05, Stationary Battery Areas

UFC 3-530-01, Design: Interior and Exterior Lighting and Controls

UFC 3-540-01, Engine-Driven Generator Systems for Backup Power Applications

UFC 3-550-01, Exterior Electrical Power Distribution

UFC 3-560-01, Electrical Safety, O&M

UFC 3-575-01, Lightning and Static Electricity Protection Systems

UFC 3-580-01, Telecommunications Building Cabling Systems Planning and Design

UFC 3-600-01, Fire Protection Engineering for Facilities

UFC 3-730-01, Programming Cost Estimates for Military Construction

UFC 3-740-05, Handbook: Construction Cost Estimating

UFC 4-010-01, DoD Minimum Antiterrorism Standards for Buildings

UFC 4-010-02, DoD Minimum Antiterrorism Standoff Distances for Buildings

UFC 4-020-01, DoD Security Engineering Facilities Planning Manual

UFC 4-021-01, Design and O&M: Mass Notification Systems

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE (ASD) FOR ENERGY, INSTALLATIONS, AND ENVIRONMENT (OUSD (AT&L))

http://www.acq.osd.mil/eie/IE/FEP_Policy_Program_Guidance.html

OFFICE OF THE UNDER SECRETARY OF DEFENSE (OSD) FOR ACQUISITION, TECHNOLOGY, AND LOGISTICS (OUSD (AT&L))

Utilities Metering Policy, April 16, 2013

NATURAL RESOURCES DEFENSE COUNCIL | DEPARTMENT OF DEFENSE

http://www.acq.osd.mil/dodsc/library/Siting_Renewable_Energy_Primer_5SEP13_FINAL_WEB.pdf

Working with the Department of Defense: Siting Renewable Energy Development

A-3 INDUSTRY

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

http://www.acgih.org/Store/

ACGIH Industrial Ventilation: A Manual of Recommended Practice

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

http://www.ansi.org/

ANSI B16.34, Valves

ANSI C2, National Electrical Safety Code

ANSI C37.90, Standard for Relays and Relay Systems Associated with Electric Power Apparatus

ANSI C50.13, American National Standard Requirements for Cylindrical Rotor Synchronous Generators

ANSI Z359, Fall Protection Code

ANSI 60, Drinking Water Treatment Chemicals – Health Effects

AMERICAN PETROLEUM INSTITUTE (API)

http://www.americanpetroleuminstitute.com/

API Spec 6A, Wellhead and Christmas Trees

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

http://www.asce.org/

ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

http://www.techstreet.com/ashrae?ashrae_auth_token=

ASHRAE 62.1, Ventilation for Acceptable Indoor Air Quality

ASHRAE Handbook - HVAC Applications

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

http://www.asme.org/

ASME B30.2, Overhead and Gantry Cranes (Top Running Bridge, Single, or Multiple Girder, Top Running Trolley Hoist)

ASME B31.1, Power Piping

ASME B31.3, Process Piping

ASME Boiler and Pressure Vessel Code

ASME PTC 6, Steam Turbines

AMERICAN SOCIETY FOR TESTING AND MATERIALS INTERNATIONAL (ASTM)

http://www.astm.org/Standard/standards-and-publications.html

ASTM D2216, Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

ASTM D422, Standard Test Method for Particle-Size Analysis of Soils

ASTM D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

ASTM D4750, Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)

AMERICAN WIND ENERGY ASSOCIATION (AWEA)

http://www.awea.org/

ASCE/AWEA RP 2011, Recommended Practice Compliance Large Land-based Wind-Turbine Support Structures 2011

AWEA O&M RP, O&M Recommended Practices

COOLING TECHNOLOGY INSTITUTE (CTI)

http://www.cti.org/pub/cticode.shtml

CTI ATC-105, Acceptance Test Code for Water-Cooling Towers

HEAT EXCHANGE INSTITUTE (HEI)

http://www.heatexchange.org/

Standards for Steam Surface Condensers

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

http://ieee.org/

ANSI/IEEE Std C37.90, IEEE Standard for Relays and Relay Systems Associated With Electric Power Apparatus

IEEE C2, National Electrical Safety Code (NESC)

IEEE Std 142, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems

IEEE Std 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

IEEE Std 519, IEEE Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems

IEEE Std 1069, IEEE Recommended Practice for Precipitator and Baghouse Hopper Heating Systems

IEEE Std 1453, IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

IEEE Std 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std 1613, IEEE Standard Environmental and Testing Requirements for Communications Networking Devices Installed in Electric Power Substations

IEEE Std C37.60, IEEE/IEC High-Voltage Switchgear and Controlgear – Part 111: Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems up to 38 kV

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

http://www.iec.ch/

IEC 61215, Crystalline Silicon Terrestrial Photovoltaic (PV) Modules – Design Qualifications and Type Approval

IEC 61400, Wind Turbine Generator Systems

IEC 61400-1, Design Requirements

IEC 61400-3, Design Requirements for Offshore Wind Turbines

IEC 61400-3-2, Design Requirements for Floating Offshore Wind Turbines

IEC 61400-4, Design Requirements for Wind Turbine Gearboxes

IEC 61400-5, Wind Turbine Rotor Blades

IEC 61400-11, Acoustic Noise Measurement Techniques

IEC 61400-12, Wind Turbine Power Performance Testing

IEC 61400-13, Measurement of Mechanical Loads

IEC 61400-14, Declaration of Apparent Sound Power Level and Tonality Values

IEC 61400-21, Measurement and Assessment of Power Quality Characteristics of Grid Connected Wind Turbines

IEC 61400-22, Conformity Testing and Certification

IEC 61400-23, Full-Scale Structural Testing of Rotor Blades

IEC 61400-24, Lightning Protection

IEC 61400-25, Communication Protocol

IEC 61400 26, Time Based Availability for Wind Turbines

IEC 61400-27, Electrical Simulation Models for Wind Power Generation

IEC 61646, Thin-Film Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval

IEC 62727, Photovoltaic Systems - Specification for Solar Trackers

IEC 61724, Photovoltaic System Performance Monitoring - Guidelines for Measurement, Data Exchange and Analysis

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

http://www.iso.org

ISO 14661, Thermal Turbines for Industrial Applications (Steam Turbines, Gas Expansion Turbines) -- General Requirements

ISO 26382, Cogeneration systems -- Technical Declarations for Planning, Evaluation and Procurement

ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA (IESNA)

http://www.ies.org/

The Lighting Handbook: Reference and Application

NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION (NECA)

http://www.necanet.org/neca-store/publications

NECA/IESNA 502-2006, Standard for Installing Industrial Lighting Systems

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

http://nfpa.org/

NFPA 1, Fire Code

NFPA 68, Standard on Explosion Protection by Deflagration Venting

NFPA 70, National Electrical Code

NFPA 72, National Fire Alarm and Signaling Code

NFPA 211, Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances

NFPA 214, Standard-on-Water-Cooling-Towers

NFPA 780, Standard for the Installation of Lightning Protection Systems

NFPA 850, Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

http://www.nist.gov/publication-portal.cfm

NIST Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION (NERC)

http://www.nerc.com/pa/stand/Pages/ReliabilityStandardsUnitedStates.aspx?jurisdiction=United States

BAL, Resource and Demand Balancing

CIP, Critical Infrastructure Protection

COM, Communications

EOP, Emergency Preparedness and Operations

FAC, Facilities Design, Connections, and Maintenance

INT, Interchange Scheduling and Coordination

IRO, Interconnection Reliability Operations and Coordination

MOD, Modeling, Data, and Analysis

PER, Personnel Performance, Training, and Qualifications

PRC, Protection and Control

TOP, Transmission Operations

TLP, Transmission Planning

VAR, Voltage and Reactive

UNDERWRITER'S LABORATORIES (UL)

http://www.ul.com/

UL 98, Enclosed and Dead-Front Switches

UL 98B, Outline of Investigation for Enclosed and Dead-Front Switches for Use in Photovoltaic Systems

UL 1703, Standard for Flat-Plate Photovoltaic Modules and Panels

UL 1741, Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources

UL 4703, Standard for Photovoltaic Wire

A-4 MISCELLANEOUS

BRITISH COLUMBIA MINISTRY OF ENVIRONMENT (BCME)

http://www.env.gov.bc.ca/epd/codes/landfill_gas/

Landfill Gas Management Facilities Design Guidelines

DATABASE OF STATE INCENTIVES FOR RENEWABLES & EFFICIENCY

http://www.dsireusa.org/

State Interconnection Policies

A-4.1 Service Reachback Contacts

ARMY:

USACE Reachback Operations Center (UROC);

Email: UROC@usace.army.mil or UROC@usace.army.smil.mil

NIPR website: https://uroc.usace.army.mil

SIPR website: http://uroc.usace.army.smil.mil

NAVY/MARINE CORPS:

NAVFAC Pacific (PACOM AOR)

https://portal.navfac.navy.mil/portal/page/portal/navfacpac/ce

NAVFAC Atlantic (Atlantic AORs)

NFCEL_CE_Reachback@navy.mil

Phone:

Comm: (757) 322-8302

AIR FORCE:

AFCEC Reachback Center

Email: AFCEC.RBC@us.af.mil

Phone: DSN (312) 523-6995

Comm: (850) 283-6995

A-4.2 Independent System Operators (ISOs)/Regional Transmission Organizations (RTOs)

ISO/RTO COUNCIL.

http://www.isorto.org

- United States
  - California ISO
    - www.caiso.com
  - Electric Reliability Council of Texas
    - www.ercot.com
  - ISO New England
    - www.iso-ne.com
  - MISO
    - www.misoenergy.org
  - New York Independent System Operator
    - www.nyiso.com
  - PJM Interconnection
    - www.pjm.com
  - Southwest Power Pool
    - www.spp.org
- Canada
  - Alberta Electric System Operator
    - www.aeso.ca

INDEPENDENT ELECTRICITY SYSTEM OPERATOR (IESO).

www.ieso.ca

APPENDIX B BEST PRACTICES AND REFERENCE INFORMATION

B-1 BEST INDUSTRY PRACTICES.

B-1.1 Solar Power Generation.

Solar Energy Industry Association website, http://seia.org provides information on best practices.

B-1.2 Wind Power Generation.

American Wind Energy Association website, http://www.awea.org provides information on best practices.

Additional best practices:

B-1.2.1 Site selection:

- Average wind speeds above 6 m/s (13.5 mph)
- Coordination with utility company for capacity, connections, and connection costs
- Site access constraints
- Investment (funding) approach

B-1.2.2 Environmental:

- Visual aspect and impact on important public viewpoints.
- Proximity to dwellings due to noise, shadow flicker, visual domination and reflected light.
- Ecology to include protected species found in the area either seasonally or year round. May require an Environmental Management Plan during construction and operation.
- Presence of archaeological and historical heritage artifacts may affect acceptability of a site.
- Impact on close recreational areas should be considered.
- Baseline hydrological assessment, where considered appropriate.
- Use a three step approach, 1) preliminary site assessment; 2) detail assessment requirements from local planning authority; 3) detailed assessment execution.
- Site selection discussion and rationale:
- Visual and landscape assessment. Create “zone of visual influence.” Consider sun motion and reflections.

- Noise assessment. Characterize current background noise level and provide sound level predictions.

B-1.2.3 Dialogue.

- Initial discussion and coordination with local planning authorities to identify and address potential issues to address.
- Communications plan for local planning authority and community awareness, and feedback.
- Create economic impact details, short (construction) and long (maintenance) impacts, and renewable energy impact.

B-1.2.4 Technical.

- Telecommunications. Existing systems may be affected. Coordinate with owners.
- Air Traffic. Local air traffic authorities must be consulted.
- Secured Areas: Proximities to restricted security areas should be evaluated.
- Testing. Local planning authority permission for and use of anemometers for detailed wind measurements at favorable sites. Duration of not less than 6 months and in some cases more than 1 year.
- Existing Land Uses. Discussions with landowner for best integration between land use and wind farm to include locations and access roads.
- Ground Conditions. Examine if construction areas and access is feasible. Investigate previous land uses and infrastructure for incompatibility.
- Site Access. Consult local authorities on impact of large and heavy goods movement over public and private roads and what improvements are required. Sharp turns and steep gradients may limit materials access.
- Electrical Connection. Connection to the grid can vary significantly by site. The local utility company can give information about likely connection points and connection costs.
- Draft Project Design. Create draft design showing potential number and size of turbines for use during initial project consultations.
- Safety. Assessment on tower integrity verses intended site; layout to avoid shadow flicker on roadways.

- Electrical Connections. Addressing land use and environmental impact of new transmission lines should run parallel with the wind farm development.

B-1.2.5 Operations.

- Complaint System. Owner has formal system for recording and addressing concerns.
- Accessibility: Owner/owner representative is accessible to the public for issues and status updates.

B-1.2.6 Decommissioning.

- Decommissioning. Initial site planning assessment to address decommissioning and site restoration.

B-1.3 Waste to Energy Power Plant.

The Energy Recovery Council website, www.wte.org, provides information on benefits of waste to energy plants.

B-1.4 Landfill Gas Power Generation.

The Environmental Protection Agency Landfill Methane Outreach Program, (http://www.epa.gov/lmop/index.html), provides best practices presentations and LFG project development guidance.

B-1.5 Geothermal Power Generation.

The Geothermal Energy Association website, http://geo-energy.org, provides information on best practices: http://geo-energy.org/reports/Geothermal%20Best%20Practices%20Publication%20Final%20CL188154847.pdf

B-1.6 Utility Interconnections.

Contact ISO/RTO Council members (http://www.isorto.org/pages/home) for North American Independent System Operators/Regional Transmission Organization requirements and best practices.

B-1.7 Policies and Incentives.

The Database of State Incentives for Renewables & Efficiency (DSIRE®) website (http://www.dsireusa.org/) provides a convenient summary of renewable energy policies and incentives.

General Federal and State “regulatory roadmap” flow charts are available for reference only at OpenEI (http://en.openei.org/wiki/Main_Page). Use of reference materials does not relieve designer from compliance with current laws and policies.

APPENDIX C PROJECT PLANNING CHECKLISTS

C-1 INTRODUCTION.

Use/adapt the example project questionnaire from the U.S. Department of Energy FEMP Guidance Developing *Renewable Energy Projects Larger than 10 MWs at Federal Facilities* to assist project planning.

- http://www1.eere.energy.gov/femp/pdfs/large-scalereguide.pdf

For geothermal projects, adapt the *Geothermal Regulator Roadmap* to create project development checklist or use commercial the following project development checklist, based upon project phase.

- http://en.openei.org/wiki/RAPID/Roadmap/Geo

C-2 GEOTHERMAL POWER DEVELOPMENT CHECKLIST.

Summarized from www.geo-energy.org terms and definitions.

Phase I – Resource Procurement and Identification	
Resource Development - meet at least two of the following criteria; and	
Y/N	Literature Survey Complete
Y/N	Geologic Mapping Completed, Geophysical and Geochemical Sample Sites Identified
Y/N	Geochemical and geophysical surveys in progress
Transmission Development - complete the following criteria; and	
Y/N	Internal transmission analysis complete
External Development - complete all of the following criteria to be considered Phase I.	
Y/N	Land or lease acquired
Y/N	Permitting process for exploration drilling (TGH, slim holes) underway

A completed Phase I level project will have two capacity estimates: a Possible Resource Estimate (estimated total subsurface geothermal resource energy value) and a, Possible Install Capacity Estimate (estimated installed capacity, in MW).

Phase II – Resource Exploration and Confirmation	
Resource Development - meet at least one of the following criteria; and	
Y/N	Temperature Gradient Holes (TGH) Drilled
Y/N	Slim Hole Drilled
Y/N	One Full Size Discovery Well Drilled
Transmission Development - meet at least one of the following criteria; and	
Y/N	Interconnection application submitted and queue position established
Y/N	Transmission feasibility studies underway
External Development - complete at least one of the following criteria to be considered Phase II.	
Y/N	Permit for Slim Hole Drilling Applied for or Approved
Y/N	Permit for Production Well Drilling Applied for or Approved

A completed Phase II level project will have two refined capacity estimates: a Possible Resource Estimate; and a, Possible Install Capacity Estimate.

Phase III – Permitting and Initial Development	
Resource Development - meet at least two of the following criteria; and	
Y/N	At least one full size production well drilled and operational
Y/N	At least one full size injection well drilled and operational
Y/N	Reservoir characterization completed and sustainable reservoir capacity determined
Transmission Development - meet at least two of the following criteria; and	
Y/N	Interconnection feasibility study complete
Y/N	System impact study (SIS) underway or complete
Y/N	Interconnection facility study underway
Y/N	Transmission Service Request Submitted (if appropriate)
External Development - complete at least two of the following criteria to be considered Phase III.	
Y/N	Plant permit application complete or in process
Y/N	Power purchase agreement secured or in negotiation
Y/N	Financing secured, or being secured, for portion of project construction

A completed Phase III level project has two refined capacity estimates: a Delineated Resource Estimate and a Delineated Install Capacity Estimate.

Phase IV – Resource Production and Power Plant Construction	
Resource Development - meet at least two of the following criteria; and	
Y/N	Majority of plant equipment on order
Y/N	Plant construction underway
Y/N	Production and injection drilling underway. 50% of geothermal resource confirmed.
Transmission Development - meet at least two of the following criteria; and	
Y/N	Interconnection Agreement Signed
Y/N	Transmission System Service Request studies completed
External Development - complete all of the following criteria to be considered Phase IV.	
Y/N	Plant permit(s) approved
Y/N	EPC contract signed
Y/N	PPA secured

A completed Phase IV level project have two refined capacity estimates: a Confirmed Resource Estimate and a Confirmed Install Capacity Estimate.

APPENDIX D PROJECT DESIGN PLANNING

D-1 INTRODUCTION.

Address areas and tailor as applicable for energy source.

D-1.1 Physical Space Requirements.

- Operation and maintenance space.
- Cooling system space.
- Fuel storage space.
- Ventilation (cooling air intake and exhaust).
- Electrical panels, transfer switches, control panel spaces.
- Exhaust system space and silencer location.
- Starting system (electrical/air start).
- Collection piping and infrastructure.
- Transmission infrastructure.
- Site access.

D-1.2 Power Rating.

- Design to power requirement.

D-1.3 Start Times.

- Maximum time to start and be ready to assume load, including black start and emergency application, and procedures.

D-1.4 Emissions.

- Exhaust gas composition and particulate limits.
- Condensates and ash.
- Noise. Equipment and total plant.
- Thermal (air/water).
- Odors.
- Visual vapors (steam, water).

D-2 ELECTRICAL.

D-2.1 Generator and Inverter.

- Electrical load (kVA) – facility loads plus loads e.g. fans, fuel pumps, lighting, and battery charging.
- Motor starting kVA.
- Nonlinear loads and effect on generator rating.
- Power factor.
- Turbine/engine-generator application – single set / parallel.
- Frequency bandwidth (steady state).
- Frequency regulation maximum – no load to full load.
- Voltage regulation – no load to full load.
- Voltage bandwidth – steady state.
- Frequency – 50/60 Hz.
- Voltage – output volts.
- Phases – 3 phase, wye / delta, single phase.
- Max step load increase – kVA.
- Transient recovery time – seconds (voltage and frequency).
- Maximum voltage deviation (transient).
- Maximum frequency deviation – Hz.

D-2.2 Protection.

- Subtransient reactance – percent (minimum).
- Switchgear/breaker size, location, characteristics, enclosure.

D-2.3 Automatic Transfer Switch.

- Sizing, controls, transfer options.
- Coordination of ground fault protection (four-pole/three pole).
- In-phase protection for large motors downstream of transfer switch.
- Define sequence of operation "Upon loss of normal power…" Define load shedding, motor starting sequence, if required, multiple generator operation, method of return to normal power (time delays).

D-2.4 Starting System and Operation Controls.

- Black start requirements.
- System operational controls and emergency shutdown.

D-2.5 Additional Circuits

- Pumps, pumps, heaters, piping heat-trace, cooling towers, cranes, conveyors, cathodic protection.

D-2.6 Grounding.

- System Grounding.
  - Grounding Electrode System.
  - Bonding.
  - Ground Fault Protection.
  - Transient Voltage Surge Suppression.
- Equipment Grounding.
  - Component Grounding.
  - Electronic Equipment Grounding.
- Generator grounding - ungrounded, solidly-grounded, impedance-grounded.
- Substation Grounding
  - Safety Criteria and Exposure Mechanisms.
  - Soil Parameters.
  - Surfacing.
  - System Parameters.
  - Ground Grid Design.
  - Fence Grounding.
- Static and Lightning Protection Grounding.
- Testing Criteria and Methodology.

D-2.7 Lighting.

- Normal lighting.
- Emergency lighting.
- Outdoor enclosure lighting (access for controls).

D-2.8 Communications.

- Equipment authority to operate certificates.

D-3 MECHANICAL.

D-3.1 Engine.

- Installation elevation above sea level (derating).
- Maximum speed (rpm).
- Fuel consumption/flow.
- Starting system.
- Ambient temperature extremes (HVAC, derating).
- Vibration limitations.
- Ancillary equipment.

D-3.2 Fuel System.

- Fuel level controls.
- Fuel transfer pump.
- Supply line/return line routing.
- Pressure.
- Flow (CFM, tons/hour, GPM).

D-3.3 Lube-Oil System.

- Integral to equipment.
- External to equipment.
- Space and provision for changing the oil.

D-3.4 Governor.

- Type.
- Frequency bandwidth (steady state).
- Frequency regulation maximum – No load to full load.

D-3.5 Cooling.

- Heat exchanger location (local/remote).
- Cooling system design (local/remote heat exchanger)

- Maximum summer outdoor temperature (ambient).
- Minimum winter outdoor temperature (ambient).
- Cooling medium (e.g., glycol/water, raw water).

D-3.6 Plant Climate Control.

- Cooling capacity.
- Maximum summer indoor temperature.
- Minimum winter indoor temperature.
- Heating capacity.

D-3.7 Generator Controls.

D-3.8 Exhaust System.

- Insulated / non-insulated.
- Silencer.
- Scrubbers.
- Penetration.
- Exhaust considerations: flappers, gooseneck, bird-screen, rain shields.

D-3.9 Sound Limitations

- OSHA, State, City Ordinances, Post/Base regulations.
- Mechanical noise mitigation (interior/exterior). Baseline monitoring.
- Combustion-air intake noise mitigation (interior/exterior).
- Exhaust noise mitigation (exterior).
- Posting of signage - Hearing Protection Required.

D-3.10 Safety.

- Guarding of mechanical hazards.
- Posting of signage for equipment which may auto-start.
- Insulation of hot equipment.
- Enclosure of electrical hazards.
- Fall protection.

D-4 CIVIL/STRUCTURAL.

- Seismic zone design compliance. Baseline monitoring.
- Vibration isolation.
- Foundation, house-keeping pads.
- Wind turbine site and structure, ASCE/AWEA RP2011, Chapter 9.

D-5 ARCHITECTURAL.

- Code and compatibility compliance.
- Bird nesting prevention.
- Climate specific corrosion resistance materials.

APPENDIX E O&M CRITERIA AND TIMING

E-1 MAINTENANCE CATEGORIES.

Maintenance falls under two categories, preventive maintenance, and predictive maintenance.

E-1.1 Preventive Maintenance.

Preventive, or time-based, maintenance is based upon equipment manufacturer's recommendations; supplemented by local knowledge.

E-1.2 Predictive Maintenance.

Predictive, or condition-based, maintenance activities are based upon feedback analysis from sensors placed on or in the equipment. The goal of predictive maintenance is to allow for advanced parts ordering, scheduling work, and planning for the repair-refurbish activities. An effective predictive maintenance program will minimize unplanned outages and maximize equipment power generation. A predictive maintenance program for critical components will dramatically reduce the threat of sudden and unexpected failures in these components, and the overall system.

E-2 O&M CRITERIA

Base O&M upon specific site requirements, available resources, and installed equipment. Obtain equipment specific training and certifications, such as those provided by manufactures or a nationally accredited program, for personnel maintaining systems. Use equipment manufacturer's recommended O&M guidelines and the following information to assist in developing O&M practices for applicable energy systems. Table E-1 provides a sample checklist.

E-2.1 Solar PV.

Use *Solar Access to Public Capital (SAPC) Working Group Best Practices in PV System Operations and Maintenance* Version 1.0, March 2015, as a reference for the O&M program (http://www.nrel.gov/docs/fy15osti/63235.pdf).

Table E-1 Sample Solar PV O&M Procedures

MAINTENANCE PROCEDURES	General Inspection	
Required Maintenance Actions	**Frequency**	**Crew Size**
Perform regular system monitoring, review system reports, respond to system alarms, and re **Travis McLeod, P.E.** Vice President port system failures based on severity level.	Daily	1
Check for insect and rodent infestation.	Monthly	1
Clean all equipment items from dust buildup.	Monthly	1
Clean all debris.	Quarterly	1
Ensure roof penetrations are watertight.	Semi-annual	2
Check for new vegetation growth or other shade items.	Semi-annual	1
Check for ground erosion near footings.	Semi-annual	1
Confirm proper signage is in place.	Semi-annual	1
Confirm electrical enclosures are secured and accessible to authorized personnel only.	Semi-annual	1
Check for corrosion on enclosures and mounting system.	Semi-annual	1
Check for low hanging wiring.	Semi-annual	1
Check for animal infestation.	Semi-annual	1
Perform site visits.	Semi-annual	2
Check all the system conduits, junction boxes, and connections for damage.	Semi-annual	2

MAINTENANCE PROCEDURES	**PV Modules**	
Required Maintenance Actions	**Frequency**	**Crew Size**
Inspect for defects such as delamination, broken glass, burn marks, cracking, and discoloration.	Semi-annual	2
Clean PV modules using demineralized water.	Semi-annual	2
Check for loose or exposed wiring.	Semi-annual	2
Test voltage / current through wires and PV modules.	Semi-annual	2
Check for shading by trees, objects, facilities around modules.	Semi-annual	1
Inspect components for moisture.	Annual	2

MAINTENANCE PROCEDURES	**Mounting System/Support Structure**	
Required Maintenance Actions	**Frequency**	**Crew Size**
Check array structure mechanical security.	Quarterly	2
Inspect for defects such as corrosion, missing or broken clips/bolts, rust, and corrosion.	Semi-annual	2
Check integrity of all penetrations.	Semi-annual	2
Grease actuator gears and filling hydraulic fluid on track components, if applicable.	Semi-annual	2
Make seasonal tilt adjustments, if applicable.	Semi-annual	2
Check proper alignment on tracking components, if applicable.	Semi-annual	2

MAINTENANCE PROCEDURES	**Combiner Box**	
Required Maintenance Actions	**Frequency**	**Crew Size**
Re-torque all connections. Repair or replace the cabling, if applicable.	Semi-annual	1
Check for debris and water intrusion inside of enclosure.	Annual	1
Check status of breakers/fuses.	Annual	1
Check for switch blockage or obstruction. Clean switch contacts.	Annual	1

MAINTENANCE PROCEDURES	Disconnect Switch	
Required Maintenance Actions	**Frequency**	**Crew Size**
Perform visual inspection.	Bi-annual	1
Inspect, operate, adjust, and lubricate mechanical linkages. Replace components as required.	Annual	2
Verify operation of mechanical interlocks.	Annual	2
Inspect and dress current carrying contacts in accordance with manufacturer's recommendations.	Annual	2
Perform insulation resistance test using a megohmeter of each critical load switch.	Annual	2
Perform contact resistance test on each critical load switch.	Annual	2
Perform thermal imaging of modules, inverters, and combiner boxes while under resistive load.	Annual	1
Repair enclosure rust spots and paint if needed.	3 years	1
Inspect the base and mounting for loose bolts and insecure or inadequate support and tighten.	3 years	1
Clean and inspect ventilators, replace as needed.	3 years	1
Check bolts on the buses and splices for manufacturer's recommended torque.	3 years	2
Inspect insulators for chipped or broken porcelain, excessive dirt film, and tracking; clean as necessary; replace broken insulators; tighten base and cap bolts.	3 years	2
Verify space heater operation or operate continuously to overcome thermostat malfunction.	3 years	2
Ensure the main switch blades are proper seated in the contacts; operate the switch several times and see that blades are properly aligned to engage contacts; clean contact surfaces if corroded; lubricate; tighten bolts and screws.	3 years	2
Check pressure springs in contact and hinge and replace, if not adequate; replace flexible shunts, if frayed.	3 years	2
Confirm that blade latches, where provided, are engaged; check latches for proper engaging and holding blade against opening force. See that stops are in place and tight.	3 years	2
Check for condition, alignment, and proper operation of arc chutes and interrupter device.	3 years	2
Adjust mechanism and linkage for adequate contact	3 years	2

closure and over travel; lubricate.		
Check and tighten bolts, screws, and locknuts; see that rods, levers, and cranks are in serviceable condition and repair as necessary; lubricate pivot points and bearings.	3 years	2
Check gears and bearings; flush out oil or grease and re-lubricate.	3 years	2
Check motor operation and Megger®; check adjustment of brake.	3 years	2
Check condition of contacts and refinish with fine file if burned or corroded; check contact springs, operating rods, and levers; check closing and opening positions with respect to main switch contacts, travel, or motor mechanism.	3 years	2
Check functional test of door and interlocks for proper sequence.	3 years	2
Lubricate switch disconnect studs and finger clusters (if drawout type) unless manufacturer's instruction says otherwise.	3 years	2
Clean and inspect cable terminations and connections for surface tracking; check connections for correct tightness.	3 years	2
Check calibration of meters (if applicable).	3 years	2
Check fuse clips for adequate spring pressure and proper fuse rating.	3 years	2
Check base and operating handle ground connections; see that ground cable is not broken.	3 years	2
Evaluate and make necessary repairs on potential, current, and control transformers.	3 years	2
Confirm that switch operating hot sticks are in good condition and are kept in a dry place; inspect hot sticks for damage and deterioration; discard suspect switch operating hot sticks; test hot sticks per requirements under FIST Volume 4-1B, section 25.	3 years	2
Review equipment ratings.	5 years	1

MAINTENANCE PROCEDURES	Inverter	
Required Maintenance Actions	**Frequency**	**Crew Size**
Verify proper operation of cooling fan. Remove debris from fan and filter.	Monthly	1
Conduct visual inspection (interior and exterior)	Quarterly	1
Inspect heat sink for debris. Check for debris and water intrusion inside enclosure.	Semi-annual	1
Re-torque all connections. Inspect all connections and replace damaged wiring.	Semi-annual	1
Inspect enclosure door seal and replace, if damaged.	Semi-annual	1
Verify installed software is current.	Annual	1

E-2.2 Wind Power Generation.

Use AWEA *Operations and Maintenance Recommended Practices*.[1] This manual presents recommendations for gearboxes, generators, rotors/blades, towers, data collection and reporting, balance of plant, warranty, and condition monitoring. Use ASCE/AWEA RP2011, Chapter 10, for structure inspection criteria.

E-2.3 Waste to Energy Power Plant.

Require builder to provide equipment manufacturers' recommended operation and maintenance practices for installed equipment. Use recommended operation and maintenance practices to generate O&M checklist and frequency. See Chapter 6 for typical waste to energy power plant equipment.

E-2.4 Landfill Gas Power Generation.

Require builder to provide equipment manufacturers' recommended operation and maintenance practices for installed equipment. Use equipment manufacturers' recommended practices to generate O&M procedures and frequency checklist for installed equipment.

Recommended documentation may include:

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[1] http://www.awea.org/oandm

- Daily reading and log sheets;
- Individual extraction well logs
  - Individual monitoring probe logs
  - Regulatory monitoring data logs
  - Generator operation parameters
- Records of gas or electricity sold;
- Maintenance schedules per manufacturer's recommendation and frequency;
- Record of maintenance performed and parts used;
- Consumables, lubricant and chemicals used; and
- Equipment calibration records.

E-2.5 Geothermal Power Generation.

Require builder to provide equipment manufacturers' recommended operation and maintenance practices for installed equipment. Use equipment manufacturers' recommended practices to generate O&M procedures and frequency checklist for installed equipment. Installed equipment may include:

- Blowout preventer(s);
- Separator(s);
- Valves;
- Pipe lines; steam/brine supply and re-injection system;
- Heat exchanger including pre-heater, vaporizer and recuperator exchanger;
- Turbine and accessories;
- Generator and accessories;
- Condenser;
- Auxiliary systems (e.g. compressors, pumps, HVAC, fire, cooling systems, drainage systems, detecting systems);
- Control system(s);
- Electrical components (e.g. switch gears, bus bars, transmission lines); and
- Emergency stand by diesel generator.

Table E-2 provides a sample inspection checklist:

Table E-2 Sample Geothermal O&M Checklist

Daily
• Check for system warnings, correct and clear as necessary.
• Check generator, turbines, gearbox, pipes, feed pump and oil pumps for vibrations, noise or oil leaks, repaired as necessary
• Check/record power output and compare against design/historical for trend
• Adjust the settings to operate within set parameters
Weekly
• Record flows and power output, and compare against design point values. Adjust/bleed condenser air to operate within set parameters.
• Check oil levels; fill as necessary. Replace oil as manufacturer's recommended frequency.
• Verify proper operation of control valves.
• Inspect for vibrations of turbine, generator gearbox and feed pump.
• Check valve shafts and feed pump mechanical seal for leaks.
Monthly
• Check valve shafts and pump seals for leaks.
• Check the oil ring in the bearing housings visually.
• Check battery(s)
• Check for hot spots in the power and control cabinets
• Clean strainers
• Replace filter elements
• Grease all motors and couplings according to manufacturer's instructions.
Semi-Annual
• Perform monthly inspection actions.
• Tighten all construction bolts.
• Check for leaks (use a leak detector).
• Verify tightness of all power terminals and cables.
• Grease all electrical motors and couplings.
• Change gearbox oil check oil, perform oil analysis.
Annual
• Perform 6-month inspection actions.
• Check feed pumps shut-off pressure.
• Perform equipment maintenance as required by manufacturer.
• Check turbine/gearbox alignments, correct if required.
• Replace oil in lubrication system(s).
• Check for leaks.
• Calibrate gages and transducers.

• Check/repair contractors.
• Replace filters in the hydraulic block.
• Check/adjust lubrication systems.

Two Years
• Perform annual inspection.
• Perform internal turbine inspection
• Test pump performance; check and repair feed pumps mechanical seals.
• Perform manufacturer’s generator and gearbox preventive maintenance.
• Visual inspect supply and re-injection pipe, exchangers, for scaling/pitting; repair as necessary.

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APPENDIX F COST PLANNING

F-1 CREST

NREL website provides the comprehensive renewable energy 'Cost of Renewable Energy Spreadsheet Tool' (CREST) for solar, wind, and geothermal renewable energy systems. Models are located at https://financere.nrel.gov/finance/content/crest-cost-energy-models. Use these models for preliminary project evaluations.

F-1.1 Landfill Gas

For landfill gas projects, perform simple payback analysis.

F-1.2 Geothermal

For geothermal projects, use Table F-1 planning factors, or more current, if available, in project payback analysis.

Table F-1 Example 50 MW Geothermal Power Plant Planning Factors

Phase	Subfactors	Installed Cost*
Field Work and Power Plant Planning Factor		$3-5,000+ / kW
Example 50MW Plant	Resource Identification	<1% of total cost, ~ $14/kW
	Resource Evaluation	8% of total cost, ~ $300/kW
	Test Well	5% of total cost, ~ $169/kW
	Production Wells	38% of total cost, ~ $1,376/kW
	Plant Construction	49% of total cost, ~ $1,800/kW
Operations and Maintenance Planning Factor		$0.01-0.03 / kWh

*Installed costs is highly dependent upon drilling costs, which, in turn, is affected by drilling activity supporting oil and gas exploration, especially shale fracking, as it uses the same type drilling equipment.

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APPENDIX G GLOSSARY

G-1 ACRONYMS

AC	alternating current
ACI	Activated Carbon Injection
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
AWEA	American Wind Energy Association
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
AFI	Air Force Instruction
AGC	Automatic Generation Control
AHJ	Authority Having Jurisdiction
APC	Air Pollution Control
BACT	Best Available Control Technology
BOP	Blowout Preventer
BOS	Base Operating Support
BTU	British thermal units
C	Celsius
CAA	Clean Air Act
CCTV	closed circuit television
CEMS	Continuous Emission Monitoring System
cf	cubic foot
CFM	cubic feet per minute
CFR	Code of Federal Regulations
CH_4	methane
cm	centimeter
CO_2	carbon dioxide
CSAMT	Controlled Source Audio-Frequency Magnetotellurics
CTI	Cooling Technology Institute
CWA	Clean Water Act
cy	cubic yard(s)
DC	direct current
DCS	Distributed Control System
DOE	Department of Energy
DSIRE	Database of State Incentives for Renewables & Efficiencies
EA	Environmental Assessment
ECIP	Energy Conservation Investment Program
EG	Emissions Guidelines
EGS	Enhanced Geothermal System
EIS	Environmental Impact Statement
EO	Executive Order
EPA	Environmental Protection Agency
EERE	Energy Efficient Renewable Energy

EPRI	Electric Power Research Institute
EPACT	Energy Policy Act
ESPC	Energy Savings Performance Contract
EUL	Enhanced Use Lease
F	Fahrenheit
FAA	Federal Aviation Administration
FERC	Federal Energy Regulatory Commission
FEMP	Federal Energy Management Program
fps	feet per second
ft.	foot/feet
ft^2	square foot/feet
ft^3	cubic foot/feet
H_2S	hydrogen sulfide
HAWT	Horizontal Axis Wind Turbine
HCl	hydrogen chloride
HF	hydrogen fluoride
HEI	Heat Exchange Institute
HDPE	high density polyethylene
HVAC	Heating, ventilation, and air conditioning
GHG	Greenhouse Gas
GSU	generator setup
IAQ	indoor air quality
ICS	internet connection sharing
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP	intermediate pressure
ISO/RTO	Independent Systems Operators/Regional Transmission Operators
IREC	Interstate Renewable Energy Council
ICS-CERT	Industrial Control Systems Cyber Emergency Response Team
in	inch(es)
IP	Induced Polarization
ISO	Independent System Operators
kg	kilogram
kJ	kilojoule
km	kilometer
kW	kilowatt
kWh	kilowatt-hour
lb	pound
LCOE	Levelized Cost Of Energy
LEL	Lower Explosive Limit
LFG	Landfill Gas
LIDAR	Light Detection and Ranging
l/s	liters per second
LFRT	low frequency ride through
LVRT	low voltage ride through
m	meter
m^2	square meter

m^3	cubic meter
mi	mile
MCR	Maximum Combustion Rate
M&V	Measurement & Verification
MJ	megajoule
MNS	Mass Notification System
MPa	megapascal
mph	miles per hour
m/s	meters per second
MSW	Municipal Solid Waste
MSW-DST	Municipal Solid Waste Decision Support Tool
MT	magnetotellurics
MTR	Military Training Route
MW	megawatt
MWh	megawatt-hour
NC	Noise Criteria
NCG	non-condensable gases
NAAQS	National Ambient Air Quality Standards
NFPA	National Fire Protection Act
NECA	National Electrical Contractors Association
NERC	North American Electric Reliability Corporation
NREL	National Renewable Energy Laboratory
NPSH	Net Positive Suction Head
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_3	ammonia
NOx	nitrous oxide
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
NSPS	New Source Performance Standards
NSR	New Source Review
NTEP	National Type Evaluation Program
O_2	oxygen
OSD	Office of te Secretary of Defense
OSHA	Occupational Safety and Health Acto
OEBGD	Overseas Environmental Baseline Guidance Document
O&M	Operations and Maintenance
ϕ	phase
PAC	Powered Activated Carbon
pH	measure of acidity or basicity of an aqueous solution
PPA	Power Purchase Agreement
ppb	parts per billion
ppm	parts per million
PSD	Prevention of Significant Deterioration
psi	pounds per square inch
PTC	Production Tax Credits
PV	photovoltaic
PVC	polyvinyl chloride

RCRA	Resource Conservation and Recovery Act
REC	Renewable Energy Credit
REO	Renewable Energy Optimization
RO	reverse osmosis
rpm	rotations per minute
RPG	Renewable Power Generation
RPS	Renewable Portfolio Standards
RTI	Research Triangle Institute
RTU	Remote Terminal Unit
s	second
SCADA	Supervisory Control and Data Acquisition
SCR	Selective Catalytic Reduction
SGHAT	Solar Glare Hazard Analysis Tool
SIS	System Impact Study
SNCR	Selective Non-catalyst Reduction
SO_2	sulfur dioxide
SP	Self-Potential
sq	square
TDEM	Time Domain Electromagnetics
tpd	tons per day
TSWEG	Tri-Service Electrical Working Group
UESC	Utility Energy Service Contract
UFC	Unified Facilities Criteria
UPS	uninterruptable power supply
UV	ultraviolet
V	volt(s)
VAWT	Vertical Axis Wind Turbine
VES	Vertical Sounding
VOC	volatile organic compound
wc	water column
WTE	waste to energy
yd^3	cubic yard

G-2 DEFINITIONS OF TERMS

3D Seismic Tomography: Uses seismic waves produced by explosives or vibrators to produce a 3D image. Common in oil and gas industries.

Aeromagnetics: Detects subsurface magnetic fields from aerial flights. Detects demagnetization from low temperature geothermal alteration. Much of US already surveyed.

Controlled Source Audio-Frequency Magnetotellurics (CSAMT): Similar to MT, but uses a man-made signal source. CSAMT has significantly less depth range than MT, at less than two miles (1.6 km).

DC Resistivity, Electrical Resistivity, Schlumberger, Vertical Sounding (VES): Uses electrical currents to measure resistivity/conductivity. Effective depth is proportional to distance between electrodes.

Energy Resilience: The ability to prepare for and recover from energy disruptions that impact mission assurance on military installations.

E-Scan: Proprietary DC method.

Gravity: Measures gravitational field to determine subsurface rock density.

Induced Polarization (IP): Uses direct current residual conductivity measurements. May be difficult to interpret.

Magnetotellurics (MT): Measures subsurface electricity created by naturally occurring magnetic fields. Indirectly detects temperature and permeability patterns. Can measure several miles deep and can be used to develop 3D images.

Paleomagnetics: Laboratory based measurement of magnetic field variations (rotation) in rock samples to determine crust dilations use to predict possible geothermal.

Time Domain Electromagnetics (TDEM or TEM): Uses manmade magnetic field to determine subsurface conductivity. TDEM has less distortion than other electrode based techniques.

Self-Potential (SP): Uses electrodes to measure natural subsurface electrical potentials. Useful when shallow groundwater flow is of interest

Synthetic Aperture Radar (InSAR): Uses changes in data from two separate flights, on two different dates, to detect subsidence or inflation between flight dates. Changes may indicate volume changes caused by reservoir pumping, or cooling of rock.