U.S. DEPARTMENT OF ENERGY

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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Renewable Energy Opportunities at Fort Hood, Texas

AE Solana
WM Warwick
AC Orrell
BJ Russo
KR Parker
MR Weimar
JA Horner
A Manning

November 2011

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

This report presents the results of Pacific Northwest National Laboratory's (PNNL) follow-on renewable energy (RE) assessment of Fort Hood. Fort Hood receives many solicitations from renewable energy vendors who are interested in doing projects on site. Based on specific requests from Fort Hood staff so they can better understand these proposals, and the results of PNNL's 2008 RE assessment of Fort Hood, the following resources were examined in this assessment:

- Municipal solid waste (MSW) for waste-to-energy (WTE)
- Wind
- Landfill gas
- Solar photovoltaics (PV)
- Shale gas

This report also examines the regulatory issues, development options, and environmental impacts for the promising RE resources, and includes a review of the RE market in Texas.

The most promising renewable energy development options for Fort Hood are wind, solar PV, and WTE, but each resource has economic, availability, or site constraint challenges. However, there were no major environmental or regulatory issues identified that would prevent the development of these renewable projects. Shale gas and landfill gas were found to have insufficient availability on or near the site for development.

Because of the moderate wind resource at Fort Hood, an on-site project is not economic at this time. It is more likely that a project off-site with a better wind resource will be more economic, although the additional transmission costs may offset any advantage such a project would have. Fort Hood should explore power purchase agreement options with third-party development partners and the associated transmission fees.

While Fort Hood has a moderate solar resource, the low cost of the displaced energy (Fort Hood currently pays a 4.3¢/kWh energy charge) and moderately high system costs create a barrier to economic solar power development.

While not currently economic, roof-top solar applications appear to have wide support at Fort Hood (no land use or mission conflicts). Fort Hood should pursue roof-top solar PV projects as appropriate opportunities arise and larger scale projects if power costs increase, PV costs decrease significantly, or if new incentives become available.

Fort Hood has been selected as a net-zero waste installation, which requires the installation to take waste generation reduction measures; then incorporate aggressive reuse, recycling, and composting strategies; and finally use any remaining waste for energy production.

It is expected that Fort Hood will reduce its waste stream from 80 tons a day to 20 tons a day. Therefore Fort Hood is interested in small-scale gasification technologies. However, gasification systems are newer to the market and small WTE technologies are typically uneconomic at this

time. A detailed analysis of available technologies is needed to determine which are suitable for use at Fort Hood and other installations.

This assessment examined the development of a large-scale WTE project, which would require importing MSW. A large-scale combustion plant is close to competitive with the blended rate of electricity that Fort Hood pays, and a large-scale gasification plant is slightly more expensive per kWh. However, a large-scale, on-site WTE project is unlikely because importing MSW is not supported by Fort Hood’s environmental policies.

Table 1 summarizes the analysis of each resource.

Table 1: Summary of Potential Renewable Resources at Fort Hood

	Wind	MSW	Solar PV	Landfill Gas	Shale Gas
Resource Availability	6.5 m/s at 80 m	444,174 tons/year potentially available from surrounding area, but importing MSW is unlikely	4.7 to 6.3 kWh/m^2/day, depending on technology	None to minimal methane from onsite landfill; no nearby landfills	The geologic conditions that define a productive shale gas resource are not present
Economic Feasibility	10.3¢/kWh required for a 10% IRR	12.0¢/kWh required for a 10% IRR for a 49 MW gasification project	19.6¢/kWh – 30.9¢/kWh required for a 10% IRR, depending on technology	~11.0¢/kWh required for a 10% IRR if methane was recoverable	N/A
Major Environmental Impacts	Mission conflicts, impact to endangered species	Emissions, hazardous waste (ash), increased truck traffic	None	N/A	N/A
Development Options	Third-party developer	Third-party developer	Third-party developer for large project, ECIP funding for small or roof-mounted arrays	N/A	N/A
Development Locations	TA 60-66 or TA 40-46	Site near Clear Creek Road entrance	Various open land near substations, identified buildings	N/A	N/A
Potential Energy Generation	4,022 MWh/yr per 1.6 MW turbine. 82 MW, ~200,000 MWh/year to meet DOD 25% goal	49 MW, 385,219 MWh/year for gasification	1,502 MWh/yr per 1 MW of modules. 135 MW, ~200,000 MWh/year with ground-mounted, fixed-tilt array to meet DOD 25% goal	N/A	N/A
Land Requirements	40 – 60 acres per MW. 51 turbines to meet DOD 25% goal	5 – 10 acres total	3 – 5 acres per ground-mounted MW. 700 acres to meet DOD 25% goal	N/A	N/A
Recommendations	Pursue EDP Renewables as a development partner for off-site project	Investigate small-scale gasification projects if large-scale is not an option	Pursue opportunities for roof-top installations as economics improve	Do not pursue	Do not pursue

Table of Contents

Tables

Figures

Introduction

Pacific Northwest National Laboratory (PNNL) completed a renewable energy (RE) assessment of Fort Hood in the summer of 2008. This assessment identified Fort Hood's most promising renewable energy projects as municipal solid waste (MSW) for a waste-to-energy (WTE) project, wind energy, and ground source heat pumps (GSHP).

Fort Hood receives many solicitations from renewable energy vendors who are interested in doing projects on site. Based on specific requests from Fort Hood staff so they can better understand these proposals, and the results of PNNL's previous assessment, the following resources were examined in this follow-on assessment:

- MSW
- Wind
- Landfill gas
- Solar photovoltaics (PV)
- Shale gas

Alice Orrell and Mike Warwick from PNNL visited Fort Hood on August 2-3, 2011. Ed Frazier, Miguel Perez, and Bobby Lynn were the primary points of contact. The purpose of the site visit was to gather data, meet with site personnel, and conduct building and land surveys. On August 2, PNNL briefed the following personnel on potential renewable energy projects:

- Edwin Frazier, Directorate of Public Works (DPW)-Energy, Electrical Engineer
- Bobby Lynn, DPW-Energy, Energy Manager
- Robert Kennedy, DPW-Environmental, Air Program Manager
- John Burrow, Real Property Planning Division (RPPD), Chief
- Steve Burrow, DPW-Environmental, Manager
- Malama Chock, DPW-Environmental, Water Program Manager
- Jerry Mora, DPW-Environmental, Waste
- Cindy Young, Business Operations and Integration Division (BOID)
- Travis Clark, RPPD
- Jennifer Rawlings, DPW-Environmental

PNNL staff also spoke with Kim Musser, National Environmental Policy Act (NEPA) Specialist, and Ryan Hernandez, DPW Utility Engineer, while on site, and presented an outbrief to DPW Director Brian Dosa on August 3, 2011.

To complete this updated assessment, PNNL reviewed the assumptions from the 2008 RE assessment and updated them as necessary, determined the availability of each renewable resource, evaluated the economics for each feasible resource, investigated regulatory issues concerning RE project development, evaluated the relevant environmental issues for each feasible resource, identified potential project locations, prioritized projects, and outlined the next steps necessary for these projects.

Status of Energy at Fort Hood

Fort Hood is in a deregulated jurisdiction of Texas, and it has had multiple retail electricity providers (REP). Past REP providers include Constellation Energy and TXU. As of January 2011 Fort Hood entered into a 2-year contract with Reliant Energy.

In FY2010, total electricity consumption was 461,246 MWh, and natural gas usage totaled 1,202,422 MMBtu (352,310 MWh). Average demand was 53 MW with a peak demand of 100 MW. Based on these consumption levels, Fort Hood would need approximately 35,000 MWh of renewable energy to meet the 7.5% EPAct mandate, and 203,000 MWh of renewable energy to meet the 25% DOD requirements.

Table 2 calculates the electricity from RE required to meet the EPAct requirement of not less than 7.5% from renewables by FY 2013 and thereafter and energy required from RE to meet the DOD goal of 25% by 2025 based on the total FY 2010 electricity and energy consumptions, respectively. These calculations should use the projected electricity and energy consumption amounts of FY 2013 and FY 2025, but those projections are not currently available. Depending on growth and energy intensity reduction efforts within Fort Hood, the required electricity and energy amounts could be higher in those years.

The expectation is that the Army will meet the stricter definitions of EPAct on its way to meeting the much higher goals of the DOD. For EPAct accounting purposes, a bonus equivalent to doubling the amount of RE used or purchased is available if the RE-generated electricity is produced and used on-site at a Federal facility. That potential bonus is not accounted for in Table 2. The EPAct mandate does not consider thermal energy, but the DOD goal allows thermal energy to be included.

Table 2: RE Goals

FY10 Electricity Consumption	FY10 Energy Consumption	Electricity Required to meet 7.5% of 2013 Electricity Consumption (EPAct Requirement)	Energy Required to meet 25% of 2025 Energy Consumption (DOD goal)
461,246 MWh	813,555 MWh	34,593 MWh	203,289 MWh

It is important that economic analyses of renewable energy opportunities use realistic data on avoided energy costs. A common analytic mistake is the use of average cost per kWh — the so-called "blended" rate. Using the blended rate will lead to inaccurate results when the renewable resource is intermittent (like wind and solar) because intermittent resources cannot guarantee a reduction in peak demand. Even non-intermittent resources may not result in reduced peak demand due to periodic maintenance shutdowns and unscheduled outages. The economic analyses in this report use only the energy charge of the power bill as the "marginal rate," demand and power charges are excluded, to evaluate intermittent resources, which is admittedly conservative. The blended rate is used for economic analysis of base-load resources.

Fort Hood pays a 4.3¢/kWh energy charge to Reliant Energy that is separate from capacity-based and fixed-cost utility charges. This energy charge is the marginal rate used in the analysis for the intermittent resources: solar and wind.

Because Fort Hood has had multiple REPs in recent years, the analysis uses two blended rates: a high and a low rate to represent the range of costs Fort Hood has experienced. The high rate is 9.07¢/kWh and the low rate is 6.28¢/kWh, based on past electric bills. These blended rates were used for the base-load renewable energy resource, MSW for WTE, which is not intermittent. Fort Hood's FY2010 blended rate was 7.32¢/kWh.

Utility Infrastructure Overview

Fort Hood has four substations located around the installation, as detailed in Table 3, none of which is currently utilizing its full capacity.

Table 3: Table Summary of Fort Hood Substations

Name	Capacity	# of Feeders	Notes
Clarke Road	45 MW	5	East of Clarke Rd, between Tank Destroyer Blvd and U.S. Highway 190.
Main	179.99 MW	16	East of Hood Rd.
North Fort Hood	5.40 MW	4	Near Longhorn and Shorthorn Auxiliary Landing Strips.
West Fort Hood	99.20 MW	8	Between Clarke Rd and Clear Creek Rd, south of U.S. Highway 190.

Distribution lines run throughout the installation and there are no off-grid loads. The on-site distribution system will be privatized and it is expected that the contract will be awarded in the fourth quarter of FY2012. Fort Hood expects to pay a monthly operations and maintenance fee to the new distribution service provider, along with additional charges, as needed, for capital improvements, and repair and replacement work.

Economic Analysis Approach

In assessing the economic feasibility of renewable energy projects at Fort Hood, PNNL evaluated two business case alternatives, *(1)* investment by an independent power producer (IPP), and *(2)* Energy Conservation Investment Program (ECIP) funding. These two funding sources have the best returns on Federal investments among the available alternatives.

Under an IPP scenario, an independent power producer will finance, construct, and operate a renewable energy facility, to sell power directly to the site that hosts the energy project. This scenario is generally economic when the third-party investor can take advantage of substantial Federal and state incentives and sell the resulting power to the site at a price at or below the projected utility rate. The incentives depend on the type of renewable energy generated and may include production tax credits, investment tax credits, substantially accelerated tax depreciation of assets, reductions in sales taxes, and exemption from property tax. The incentives applicable to each resource are detailed in the Resource Investigations and Economic Analyses sections.

A 10% internal rate of return (IRR) is the assumed desired minimum return on investment for third-party developers used in the analysis of IPP opportunities. The IPP economic analysis calculates the project's cost of energy (price of generated electricity) required to achieve this 10% IRR. Therefore, this cost of energy is the minimum price at which a third party could sell the electricity to make the assumed desired return on investment. This price is determined using equipment and installation costs, O&M costs, inflation rates, interest rates, discount rates, depreciation, taxes, and tax incentives.

ECIP is one standard DOD approach for making energy efficiency and renewable energy investments using Federally appropriated funding. ECIP investment awards are made based upon savings to investment ratio (SIR) and simple payback criteria. ECIP funding is limited, and is awarded on a competitive basis within the Army — only the most economic projects can be assured funding. The approach used in the analyses follows the Federal life-cycle cost (LCC) methodology and procedures in 10 CFR, Part 436, Subpart A. The LCC calculations are based on the Federal Energy Management Program (FEMP) discount rates and energy price escalation rates. This approach is likely to understate future power costs, however; developing forecasts of future power costs is not cost-justified for screening analyses. It is only recommended for projects that may be pursued based on this analysis.

For more detailed information about the economic analysis approach, please refer to PNNL's Fort Hood 2008 renewable energy assessment report (Chvala et al. 2008).

Resource Investigations and Economic Analyses

The analyses described below considered resource availability, current costs of energy, available incentives, and siting limitations. Regulatory restrictions and incentives are described in detail in the "Regulatory Framework for Renewable Energy Project Development" section below.

Wind

The wind resource across Texas varies greatly, with the best wind resources being in west Texas and the panhandle. Central and eastern Texas, where Fort Hood is, have more moderate wind speeds as shown in Figure 1.

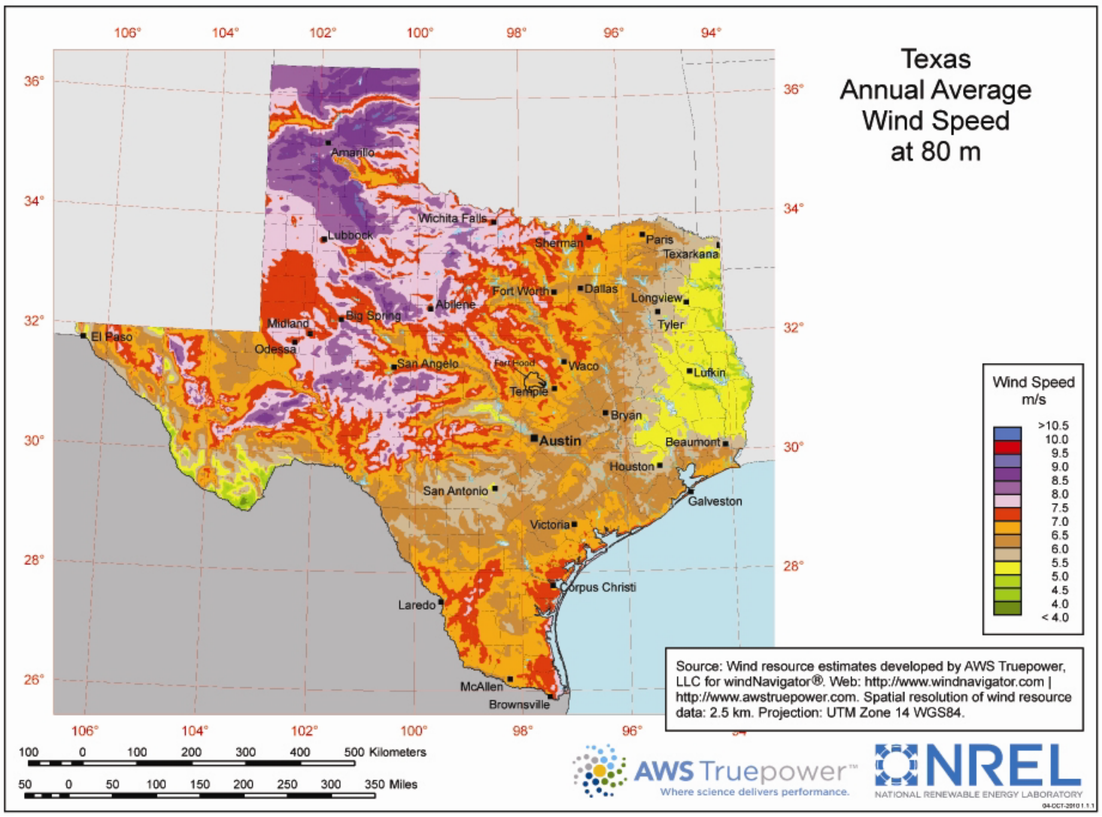

Figure 1: Texas Annual Average Wind Speed at 80 m (NREL 2010)

Resource and Siting

Various sources, shown in Table 4, were consulted to estimate the average wind speed at Fort Hood. For this assessment, the average annual wind speed was assumed to be 6.5 m/s at 80 m.

Table 4: Wind Resource at Fort Hood

Source	Wind Speed	Accessed
NASA Surface Meteorology and Solar Energy (SSE) data	5.73 m/s at 50 m, 6.5 m/s at 80 m	2008
3TIER's Firstlook online tool	5.8 m/s at 50 m, 6.3 m/s at 80 m	2008
Texas Annual Average Wind Speed at 80 m map	6.0 – 7.0 m/s at 80 m	2011

Figure 2 is the portion of the Texas wind resource map that includes Fort Hood. The outline of Fort Hood shown is that of its training areas, and does not include the main base, which is located above the "p" in "Temple" on the map. As shown with the color coding, there is a large swath of land with 6.0 – 6.5 m/s wind while the rest of the site has 6.5 – 7.0 m/s wind.

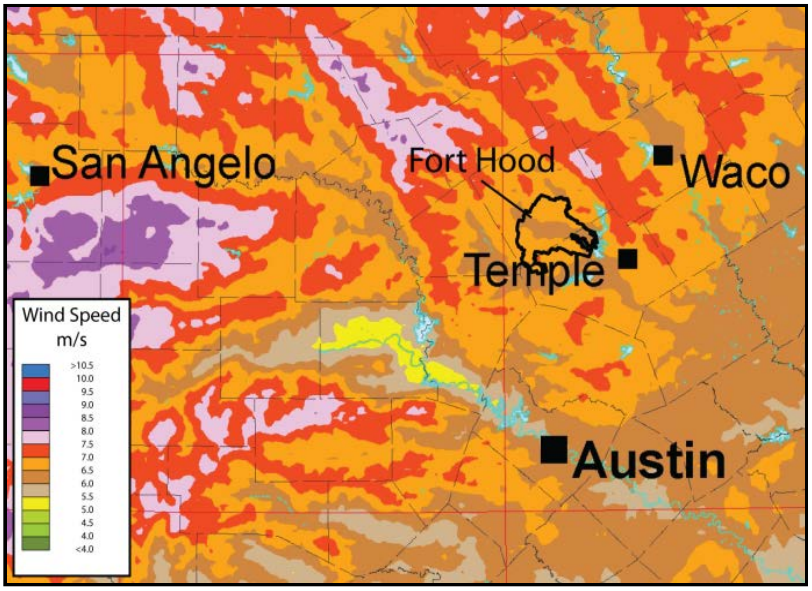

Figure 2: Fort Hood Wind Speed at 80 m (NREL 2010)

Fort Hood's Military Installation Map shows the Fort's training areas, flight routes, and site boundaries. Comparing the installation map to the wind resource map, the best potential wind project locations appear to be Training Areas (TA) 60-66 and TA 40-46. TA60-66 is the northwest corner of the site, and TA40-46 is the southwest corner. These areas avoid the central Live Fire Area and have the higher 6.5 – 7.0 m/s wind speeds.

After wind resource availability, the primary siting consideration for grid-connected wind projects is transmission availability and the capacity of those lines. Projects ideally need to be located within approximately 1 mile of existing transmission lines, or new lines will need to be constructed at considerable cost.

This analysis does not include any transmission costs and assumes that existing transmission lines are available to transmit power without substantial additional investment. It is also assumed that an onsite wind project would not trigger new standby or other fees from the local utility. Because wind is intermittent, the utility may have interconnection requirements to ensure grid stability and to ensure there is reliable power for the installation.

TA40-46, in the southwest corner, are close to 138 kV and 345 kV transmission lines, but also close to the Robert Gray Army Airfield and the Hood Army Airfield. A distribution line does run along West Range Road which divides these training areas from the Live Fire Area.

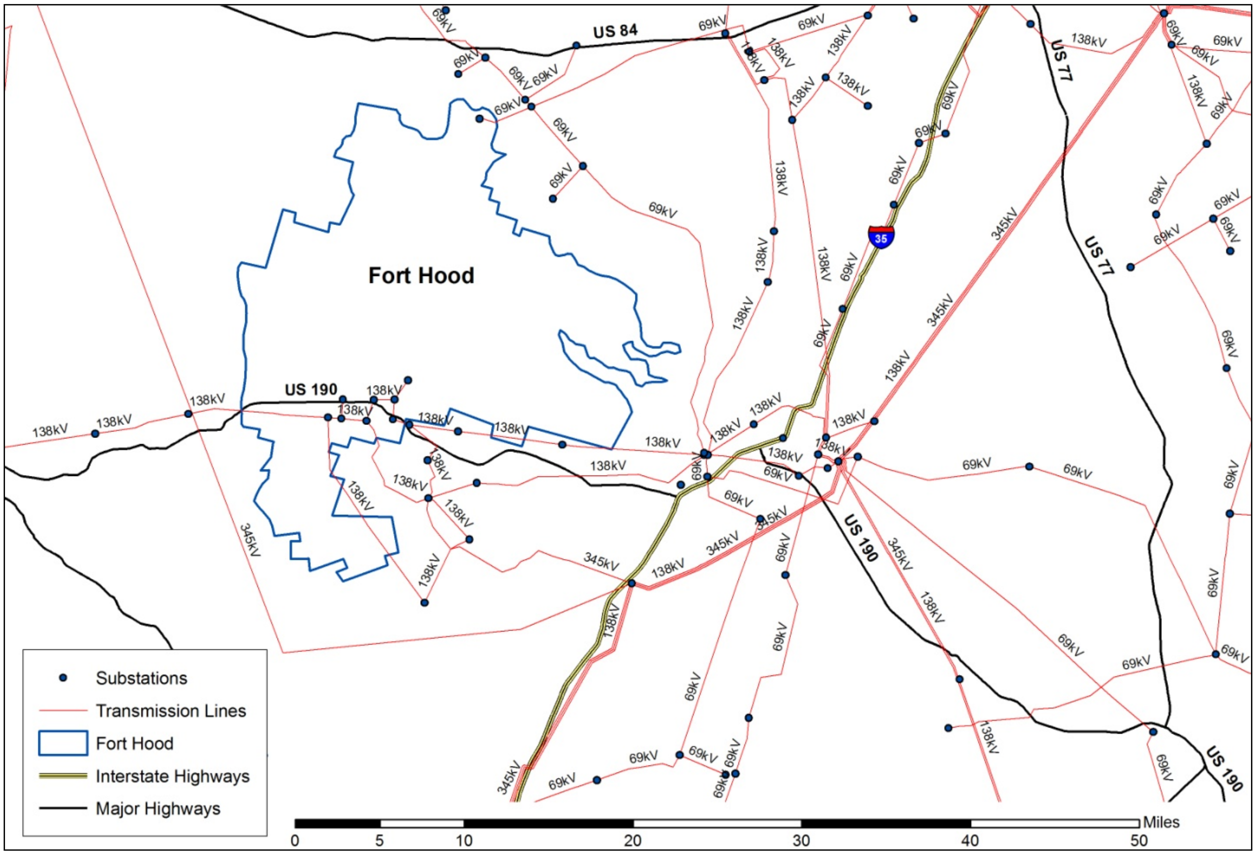

Figure 3: Area Transmission Lines (source unknown)

The Federal Aviation Administration (FAA) requires Notice of Proposed Construction for a project that meets certain criteria so that it can determine if there would be adverse impacts to air navigation safety (FAA 1999). One of the triggering criteria is whether the project would be located within 20,000 feet (3.8 miles) or less of an existing public or military airport. The Robert Gray Army Airfield is located in the southern part of the installation. The Hood Army Airfield is located in the south central part of the installation.

An additional FAA criterion, that would necessitate a Notice of Proposed Construction, is any construction or alteration of more than 200 feet (61 meters) in height above ground level. This criterion applies regardless of the distance from the proposed project to an airport. In response to the filing of a Notice of Proposed Construction, the FAA can either require project modification(s) or issue a “No Hazard to Air Navigation” determination, which would allow the wind project to proceed.

These training areas have a lot of open land with sparse trees, short grass, and low ridgelines. Tank trails run through the training lands and up some knolls and ridgelines. TA 60-66 and TA

40-46 were not specifically evaluated for any mission and training conflicts. If Fort Hood would like to pursue wind energy development in either of these areas, a formal site approval process would be required.

A summary of the weather data collected at Robert Gray Army Airfield from 1960 to 2005 was given to PNNL by Fort Hood staff. The summary shows that the prevailing wind direction at the airport is from the south. The optimal siting of wind turbines in either TA 60-66 or TA 40-46 would therefore be on ridgelines running in the east-west direction at sufficient distances from any airfields, so the turbines could face into the prevailing wind and be above any potential obstacles.

Economics

As of the end of 2010, the capacity-weighted average O&M cost for projects constructed since 2000 was $27/kW per year (Wiser and Bolinger 2011). Bloomberg New Energy Finance reports the cost of a 5-year full-service O&M contract to be $30-$48/kW per year (Wiser and Bolinger 2011). And the Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2010 report prices fixed O&M costs for onshore wind at $28.07/kW for 2010 (EIA 2011). O&M costs for a project may be lower in the early years of a project's life, and in fact, any early maintenance may be covered by a turbine's warranty. As a project ages, it is likely to require more maintenance. For projects built in the 1990s, the 2010 capacity-weighted average O&M cost was $53/kW per year (Wiser and Bolinger 2011). To capture this possible change in costs over time in an average rate, and to err on the conservative side, this analysis assumes an O&M cost rate of $40/kW per year.

The 2010 capacity-weighted average cost of installed wind projects was $2,160/kW (Wiser and Bolinger 2011) for larger projects, typically those 50 MW and larger. This installed cost figure accounts for the costs of the turbines, balance of plant equipment, interconnection, and construction. The turbines represent almost 70% of the installed cost. The overall capital cost includes this installed cost figure plus development costs, insurance, and consulting fees – everything to get a wind project to operation. The EIA's AEO 2010 report includes estimates of overnight capital costs for all types of generic utility-scale generation plants. The overnight capital cost includes all engineering, procurement, and constructions costs, project indirect costs, and owner's costs (excluding financing costs). According to the EIA, the overall capital cost for onshore wind in 2010 was $2,438/kW (EIA 2011). This analysis assumes a total capital cost (including sales tax) of $2,639/kW.

The economic and performance assumptions are detailed in Table 5. The results are show in Table 6.

Table 5: Performance, Cost, and Economic Inputs for Wind Energy

Location	TA40-46 or TA60-66	
Conditions	Standard: 1,255 kg/m3, 0°F, normal turbulence intensity	
Assumed Average Wind Speed	6.5 m/s at 80 m	
Energy Charge	4.3¢/kWh	
Total Capital Cost (including sales tax)	$2,639/kW	
Fixed O&M Cost	$40/kW	
State Franchise Tax Deduction	10%	
State Property Tax Incentive	Exempt	
MACRS Depreciation	Included	
Federal Production Tax Credit	2.1¢/kWh	
Transmission Costs	Not Included	
RECs	Not Included	
Turbine Type	GE 1.6 MW, 82.5 m rotor diameter, 80 m hub height	Siemens 2.3 MW, 101 m rotor diameter, 80 m hub height
Net Capacity Factor	28.7%	29.3%
Net Annual Energy Production per turbine	4,022 MWh/year	5,907 MWh/year

Table 6: Economic Results for Wind Energy

Financing Scenario	**ECIP**		**IPP**
Economic Factor	**SIR**	**Simple Payback, years**	**Cost of Electricity at 10% IRR**
GE 1.6 MW	0.5	28	10.6¢/kWh
Siemens 2.3 MW	0.5	28	10.3¢/kWh

The cost of energy required to achieve a 10% IRR for a large-scale wind project is not economic compared to Fort Hood's current energy charge of 4.3¢/kWh. However, whether a RE project should be evaluated solely on its economics is discussed in detail in the Development Options section presented later in this report.

Project Sizing

Because the wind economic analysis is performed on a per–kilowatt-installed basis, project size is scalable. To determine an exact potential project size, these RE goals were used as guidance. Table 7 demonstrates what it would require to meet these goals with wind energy projects, based on the estimated capacity factors and energy productions of the two turbines evaluated.

Table 7: Wind Energy Meeting RE Goals

Turbine Scenario	Project Size and Cost Required to Meet 7.5% Requirement	Project Size and Cost Required to Meet 25% Requirement
GE 1.6 MW	9 turbines, 14.4 MW, $38 million	51 turbines, 81.6 MW, $215 million
Siemens 2.3 MW	6 turbines, 13.8 MW, $36 million	35 turbines, 80.5 MW, $212 million

Finding space for 6 to 9 turbines on site at Fort Hood is probably more likely than finding space for 35 to 51 turbines. Fort Bliss is similar to Fort Hood in that they both have many acres of training land. With PNNL's assistance, Fort Bliss was able to identify conflict-free space for 6 to 8 turbines in its training land. Purchasing energy from an off-site location would most likely be required if Fort Hood is interested in a large project, given mission and training land constraints.

Municipal Solid Waste

Fort Hood has been selected as a net-zero waste installation, which means the installation must take certain measures to first and foremost reduce waste generation; then incorporate aggressive reuse, recycling, and composting strategies; and finally use any remainder for energy generation. Fort Hood's approach to meet net-zero waste goals is expected to result in a waste stream reduction of 80%, resulting in a total of less than 5,000 tons/year. Waste-to-energy (WTE) technologies are typically only cost-competitive with Army energy prices on a large-scale basis, requiring around 100,000 tons of waste or more per year. Fort Hood currently generates less than 25,000 tons/year.

Resource and Siting

Fort Hood has the option of sending its waste offsite to an existing WTE plant, developing a small WTE plant on site that uses only site waste, or importing waste to develop a large-scale project on site. There are no existing WTE plants near Fort Hood at this time (TCEQ 2011), so a new facility would need to be built to accommodate Fort Hood's waste offsite. Small WTE technologies are newer to the market and are typically uneconomic, and therefore little characterization of these technologies has been done to date. There is a need for small-scale technology recommendations, but that effort is outside of this scope. Some discussion of technology options is included in Appendix A. It is unlikely that bringing outside waste onto the installation will align with the intended net-zero waste strategy and Fort Hood's environmental policies do not support any import because of liability issues and because the waste may contain hazardous materials. However, this is the option explored in this assessment as it has the promise of being the most economically feasible.

Any WTE plant on Fort Hood will need to be located at a site with access for waste delivery, utility access to run the plant and deliver the generated power, and sufficient space for waste storage, processing, and conversion equipment. The plant location should be away from residential and commercial areas, and ideally outside of installation security to avoid hassle for waste delivery from offsite.

A potential location was identified during the site visit. It is north of U.S. Highway 190 and south of the rail line between Clarke Road and Clear Creek Road. Waste may be delivered via the highway or the rail line, and it is a relatively undeveloped area. There is an entrance gate to the installation at Clear Creek Road from which a delivery road could be diverted, if required. The Clarke Road substation is also nearby.

To determine the potential for a large-scale plant on or off site, the amount of MSW available in the area must be defined. MSW in Texas is not managed at the state level, but instead by regions, called Councils of Government (COGs). Each COG is responsible for developing and maintaining a waste management plan, as well as ensuring adequate disposal capacity is available in the region. There is no restriction on transfer of waste between regions (EPA 1995).

Fort Hood is located in the Central Texas COG (CTCOG), and is near the Capital Area COG (CAPCOG) and the Heart of Texas COG (HOTCOG). The major population centers, and therefore waste generators, in these regions are Austin/Round Rock (CAPCOG), Fort Hood/Killeen/Temple (CTCOG), and Waco (HOTCOG). Without waste from at least one of these areas, a large-scale WTE plant will not be feasible at Fort Hood.

The City of Austin has a net-zero waste policy, which is to divert 90% of waste from landfills and incinerators by 2040. It also has a policy of carbon-neutral electricity generation for all new facilities (Austin City Connection 2011). While MSW within the City of Austin will not be considered available, nearby areas that currently dispose of waste in Austin landfills will need to find other disposal options as Austin limits waste imports. Williamson County, in this case, may be a good potential source of MSW for a WTE plant.

As detailed below, Fort Hood/Killeen/Temple waste is likely available if the WTE plant would be cost-competitive with Temple Landfill's rates, and Waco area waste is likely unavailable because of the distance from Fort Hood as well as a conflict of interest with landfill operations.

Table 8 lists the landfills within 60 miles (the assumed economic waste transport distance) of Fort Hood, along with the amount of waste each collected in 2009, the expected remaining life, the landfill owner, and the entity responsible for collecting and delivering waste to the landfill.

Table 8: MSW Landfills in Counties within 60 Miles of Fort Hood[1]

Landfill Name	Location	Sources of Waste	Tons Collected/Year (2009 data)	Remaining Life (years)	Landfill Owner/Waste Collector
Fort Hood Landfill	Coryell County, on Fort Hood	Fort Hood	22,120	60	Fort Hood/Fort Hood contractors
Temple Recycling & Disposal Facility	Bell County	CTCOG	361,940	19	Temple (operated by WM)/various

[1] Various sources of information are included in References.

Table 8: MSW Landfills within 60 Miles of Fort Hood (Cont.)

Landfill Name	Location	Sources of Waste	Tons Collected/Year (2009 data)	Remaining Life (years)	Landfill Owner/Waste Collector
Texas Disposal Systems (TDS) Landfill	Travis County	Austin area	729,506	27	TDS/TDS
BFI Sunset Farms Landfill	Travis County, 66 miles from Fort Hood	Austin area, CAPCOG, Bell, Coryell, McLennon, San Saba, Milam, Mason, Washington, Burleson Counties	565,502	1	BFI (operated by Allied Waste)/ unknown
Williamson County Recycling & Disposal Facility	Williamson County, 49 miles from Fort Hood	Williamson, Mason, Lampasas, Bell, and Milam Counties	290,663	125	Williamson County (operated by WM)/Williamson County
Austin Community Recycling & Disposal Facility	Travis County, 66 miles from Fort Hood	Austin area	415,784	4	WM/Travis County
Itasca Landfill	Hill County, north of Waco, 111 miles from Fort Hood	Waco area	402,746	74	Allied Waste/unknown
City of Waco Landfill	McLennan County, 62 miles from Fort Hood	Waco, Woodway, Hewitt, and McGregor - western Waco area	244,573	18	Waco/Waco
Lacy Lakeview Recycling & Disposal Facility	McLennan County, northeast of Waco, 71 miles from Fort Hood	Waco area	100,625	10	Waste Management/unknown

Table 9 lists the counties within 60 miles of Fort Hood, along with their estimated population and waste generation rates. Local landfills used by the counties are also listed, with notes about the availability of the waste. The sources of waste generation, rather than the disposal locations, are used to determine MSW availability because the collection companies will be the ones to deliver the waste; the landfill owners are typically sources of competition.

Table 9: Waste Generation and Disposal within 60 Miles of Fort Hood[2]

County	Location	Population[3]	MSW Generation Rate[4] (lb/person/day)	Estimated Annual MSW Generation (tons/year)	Estimated Electricity Production)	Disposal Location	MSW Available for WTE?
Williamson County	CAPCOG – north of Austin	410,686	6.51	487,926	40.6 MW	Williamson County Landfill	Likely
Lampasas County	CTCOG – directly west of Fort Hood	20,915	4.98	19,009	1.6 MW	Temple and Williamson County Landfills	Likely
Hamilton County	CTCOG	8,043	4.98	7,310	0.6 MW	Temple Landfill	Likely
Falls County	HOTCOG	16,782	12.59	38,560	3.2 MW	Lacy Lakeview Landfill	Likely
Coryell County	CTCOG – northern end of Fort Hood	72,529	4.98	65,918	5.5 MW	Temple and BFI Landfills	Likely
Burnet County	CAPCOG – southwest of Fort Hood	45,149	6.51	53,640	4.5 MW	Unknown	Likely
Bell County	CTCOG – southern end of Fort Hood	285,787	4.98	259,738	21.6 MW	Temple, Williamson County, BFI Landfills	Likely
McLennan County	HOTCOG – Waco	233,378	12.59	536,227	44.6 MW	Waco Landfill	Unlikely
Milam County	CTCOG	24,628	4.98	22,383	1.9 MW	Temple, Williamson County, BFI Landfills	Unlikely
Travis County	CAPCOG - Austin	1,026,158	6.51	1,219,153	101.5 MW	BFI, TDS, Austin Community Landfills	Unlikely

[2] Various sources of information are included in References.
[3] US Census Bureau 2010
[4] TCEQ 2011

Table 9: Waste Generation and Disposal within 60 Miles of Fort Hood (Cont.)

County	Location	Population[5]	MSW Generation Rate[6] (lb/person/day)	Estimated Annual MSW Generation (tons/year)	Estimated Electricity Production	Disposal Location	MSW Available for WTE?
Mills County	CTCOG	4,994	4.98	4,539	0.4 MW	Temple Landfill	No
San Saba County	CTCOG	5,871	4.98	5,336	0.4 MW	Temple and BFI Landfills	No
Llano County	CAPCOG	18,274	6.51	21,711	1.8 MW	Unknown	No
Hill County	HOTCOG	35,840	12.59	82,349	6.9 MW	Lacy Lakeview Landfill	No
Bosque County	HOTCOG	17,631	12.59	40,510	3.4 MW	Lacy Lakeview Landfill	No

Based on this information, about 932,100 tons of waste are potentially available for use in a WTE plant each year, resulting in a potential generation of up to 78 MW. Waste is considered unlikely to be available, or not available from a county, if the waste collection location is more than 60 miles from Fort Hood, if the county is between 30 and 60 miles from Fort Hood but generates less than 50,000 ton/year of waste, or if the county's waste is collected by the same entity that owns or operates the local landfill. If Williamson County waste is not available, or is considered too far away compared to the other potential sources, about 444,200 tons of waste would be available from counties closer to Fort Hood, with a generation potential of 37 MW.

Economics

To better align with Fort Hood's electricity requirements and standard WTE project sizes, as well as to allow the large local landfills to continue operating in parallel with a WTE plant, this economic analysis assumed that only local waste would be used (444,200 tons/year, excluding Williamson County). Waste from Williamson County can be used to supplement local waste if needed. WTE provides baseload electricity, so it is best to develop a plant that can provide an amount of electricity that will be consumed by the installation at all hours (less than the average annual load of 53 MW).

As explained in Appendix A, there are two primary technologies that are considered for use with MSW plants: combustion and gasification. Both can be used for large-scale plants, although combustion has been the technology of choice in past years within the U.S. Gasification is newer to the market, and many (but not all) gasification technologies are small-scale. Fort Hood has indicated that it would prefer a gasification project.

[5] US Census Bureau 2010
[6] TCEQ 2011

Because commercial MSW plants are just now being constructed in the U.S. after a 15-year lull, it is difficult to determine accurate costs. Based on data sources consulted (Babcock & Wilcox 2011, Quinn 2011, Davis 2011, EIA 2010, Jones 2009), it is estimated that a large-scale (10 MW and greater) MSW combustion plant will cost about $5-6,000/kW and a large-scale gasification plant will cost about $6-7,000/kW. These two plant options were evaluated using the assumptions detailed in Table 10.

Table 10: Performance, Cost, and Economic Inputs for Municipal Solid Waste

Technology Type	Combustion	Gasification
Feedstock Amount	444,174 tons/year	444,174 tons/year
Plant Capacity	37 MW	49 MW
Efficiency	28%	37%
Net Capacity Factor	90%	90%
Net Annual Energy Production	291,517 MWh/year	385,219 MWh/year
Total Capital Cost (including sales tax)	$6,003/kW	$6,580/kW
Fixed O&M Cost	$99/kW	$91/kW
Variable O&M Cost	0.8¢/kWh	1.0¢/kWh
Feedstock Cost	-$10/ton	-$10/ton
MACRS Depreciation	Included	Included
Federal Production Tax Credit	1.1¢/kWh	1.1¢/kWh
Transmission Costs	Not Included	Not Included
RECs	Not Included	Not Included

A feedstock cost of negative $10/ton is used because it is assumed that some portion of current landfill tipping fees will be available to the project. In other words, the waste collection companies will pay the WTE facility to take their waste, just as they currently pay landfills. The Texas average tipping fee at landfills is $30.96/ton (TCEQ 2011). A smaller fee is assumed for this analysis because it will have to be competitive with local landfills to attract haulers to the new location.

Two cost scenarios were analyzed because of Fort Hood's varying rates from year to year with frequent changes in utility providers. A low-rate scenario uses the lowest annual average rate Fort Hood has paid in the past six years: 6.28¢/kWh. The high-rate scenario uses the highest annual average rate from the past six years: 9.07¢/kWh. The economic results based on these two scenarios and the two technologies are presented in Table 11.

Table 11: Economic Results for Municipal Solid Waste

Financing Scenario	ECIP		IPP
Economic Factor	**SIR**	**Simple Payback**	**Cost of Electricity at 10% IRR**
Combustion, low rate	0.7	21 years	10.8¢/kWh
Combustion, high rate	1.1	13 years	10.8¢/kWh
Gasification, low rate	0.6	24 years	12.0¢/kWh
Gasification, high rate	1.0	14 years	12.0¢/kWh

These results show that a large-scale combustion plant is close to competitive with the higher rates that Fort Hood has paid in the past. A large-scale gasification plant would be slightly more expensive per kWh. Both have the potential for cost-effective development with ECIP, although that approach is not recommended, as discussed in the Development Options section below. A plant could be competitive with future energy costs, especially as these technologies are more widely developed and costs begin to fall. If another $10/ton were available from tipping fees, the cost of energy would decrease by 1.2¢/kWh. If $20/ton is sufficient to attract developers even if local landfills subsequently lower their rates, a combustion plant could be economic compared to Fort Hood's higher historic electricity rate.

A small-scale gasification plant is less likely to be economic. This technology is not yet commercial for use with MSW, but estimated project costs from various manufacturers range from $6,000/kW to over $13,000/kW. Because these technologies have not been widely commercialized, costs cannot be verified. A small-scale system that would consume all of Fort Hood's approximately 20 tons/day should cost about $3-8 million, and could be installed as a demonstration project on site. It is unknown how much electricity would be generated because that value is technology-specific, but it would be marginal.

Solar PV

In the United States, the solar resource on a latitude-tilted collector varies greatly from less than 2.5 kWh/m^2/day in northern Alaska to over 7.0 kWh/m^2/day in the American Southwest. Figure 4 displays the national solar resource range in terms of insolation in units of kWh/m^2/day on latitude-tilted solar collectors.

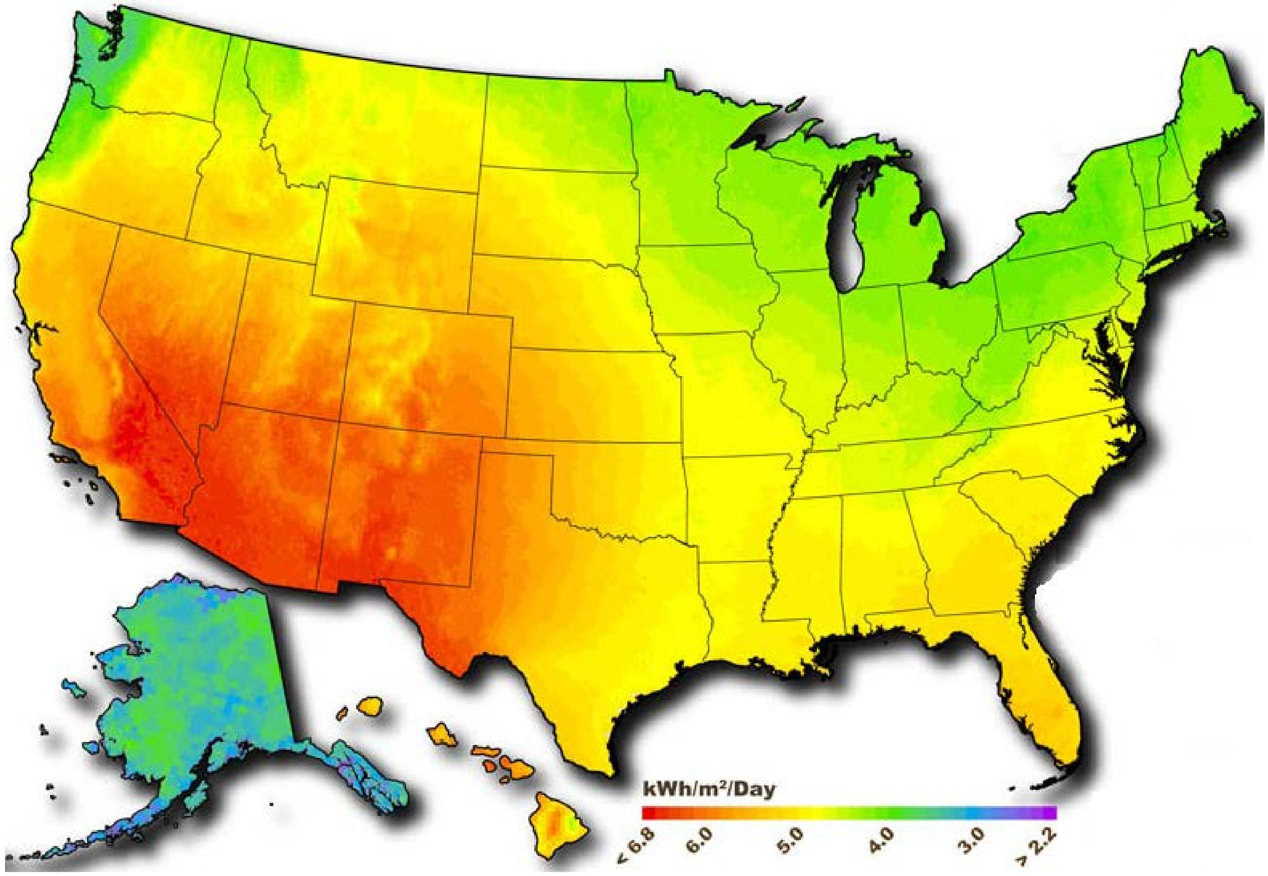

Figure 4: U.S. Solar Insolation Levels (NREL 2008)

Resource and Siting

The region around Fort Hood experiences insolation levels ranging from 4.8 to 5.8 kWh/m^2/day on a south-facing, latitude-tilted surface, which is a moderately high solar resource, as shown in Figure 5.

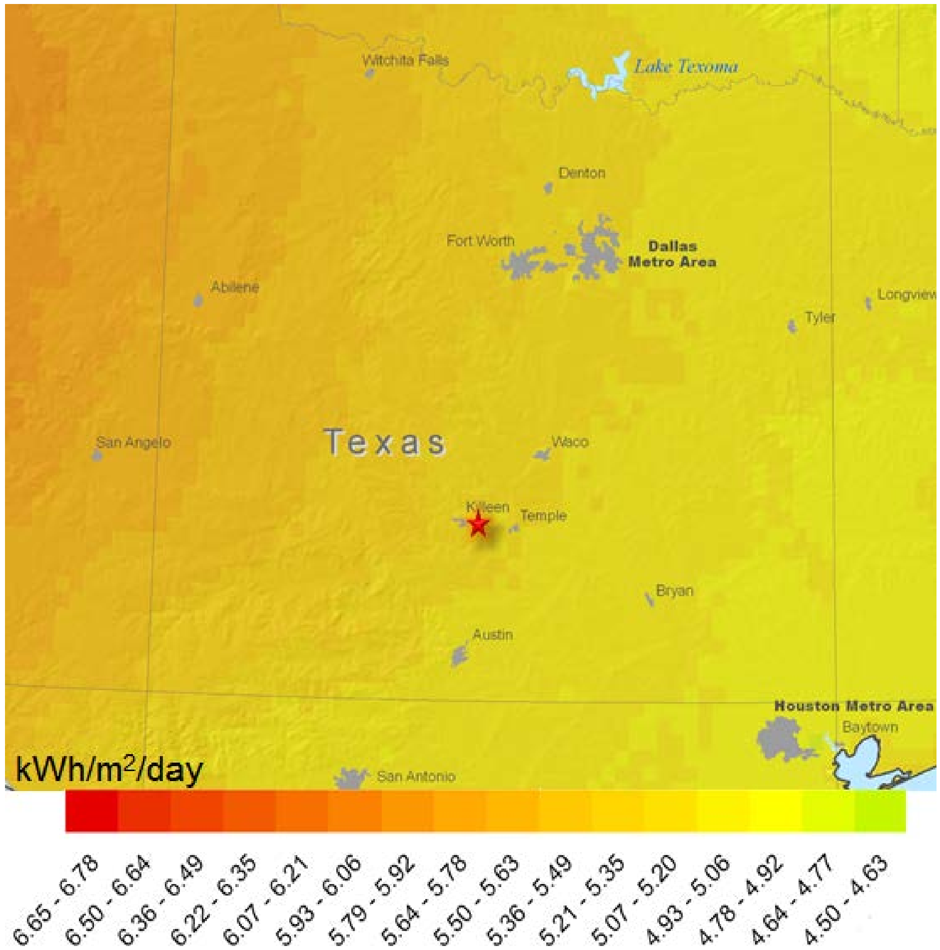

Figure 5: Fort Hood Solar Insolation Levels (NREL 2008)

Fort Hood's solar resource potential was estimated using National Aeronautics and Space Administration's (NASA) Surface meteorology and Solar Energy (SSE) data and Natural Resources Canada's RETScreen analysis software. The SSE data set is a continuous and consistent 10-year global climatology of insolation and meteorology data on a 1° by 1° grid system. Although the SSE data within a particular grid cell are not necessarily representative of a particular microclimate within the cell, the data are considered to be the average over the entire area of the cell. These estimates are sufficiently accurate for preliminary feasibility studies.

Table 12 displays the average solar insolation data for several different surface orientations. Average monthly insolation values are provided in kWh/m^2/day for the following conditions:

- Tilt 0 – Collector installed at a 0° tilt (i.e., on a flat surface such as a roof).
- Tilt (lat) – An array tilted at an angle equal to the latitude, which is a generally accepted means to optimize annual electricity production.
- Single-axis tracking – A collector capable of tracking the sun's position by rotating along an axis (e.g., a system that can tilt modules from east to west over the course of a day).

Table 12: Monthly Averaged Insolation at Fort Hood (kWh/m^2/day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Tilt 0 (flat)	2.6	3.4	4.3	5.6	6.0	6.7	7.1	6.5	5.4	4.0	2.9	2.5	4.7
Tilt 31 (lat)	3.5	4.1	4.8	5.6	5.5	6.0	6.3	6.2	5.8	4.8	3.8	3.5	5.0
Single-Axis Tracking	4.1	4.7	5.9	6.9	7.0	7.8	8.5	8.3	7.3	6.0	4.5	4.1	6.3

At Fort Hood, collectors mounted at a tilt of 0° (e.g., a flat roof), a tilt of 31° (the site's latitude), and on a single-axis tracking mount have an average yearly solar potential of 4.7, 5.0, and 6.3 kWh/m^2/day, respectively. Figure 6 shows the monthly incident solar radiation for each type of collector.

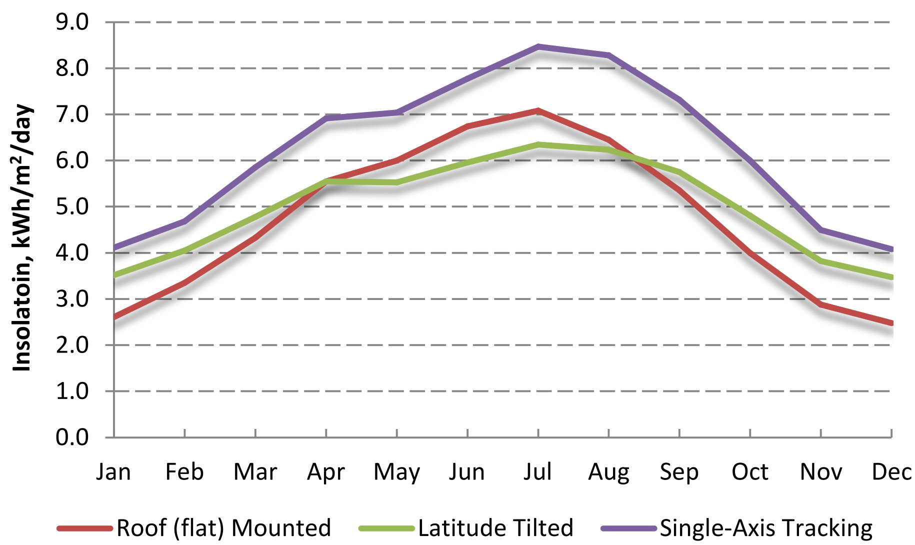

Figure 6: Average Daily Insolation at Fort Hood

Beyond the resource availability, array siting is another major consideration for grid-connected projects. A key constraint in large-scale project siting is transmission line availability and the spare capacity of those lines. Projects ideally need to be located within approximately 1 mile of existing transmission lines, or new lines will need to be constructed at considerable cost. This analysis does not assume any transmission costs, assumes that existing transmission lines are available to transmit power without substantial additional investment, and that the project will not trigger new standby or other fees from the utility. However, because the solar resource is intermittent, the utility may have interconnection requirements to ensure grid stability and to ensure there is reliable power for the installation.

Because of the inherent siting flexibility of PV arrays, the most suitable sites for arrays is frequently near existing substations with spare capacity. Potential locations at Fort Hood include:

- The small field west of the Main Substation provided this area is open. Proximity to the main gate would provide excellent project visibility. The size of the field will restrict the capacity of the array.

- The open tracks of land west and southwest of the NFH Substation.

- The abundant land around the WFH Substation. The proximity of Highway 190 would allow for ease of construction and array maintenance. Proximity to the local elementary school could provide valuable educational and visibility opportunities.

- Between Clarke Road and Clear Creek Road. Proximity to the local middle school could provide valuable educational and visibility opportunities.

- On the closed portions of the on-site landfill.

Building integrated PV systems are also suitable at Fort Hood. Modern array roof mounting brackets can avoid the need to penetrate roofs when securing the array to the building. Consequently, roof integrity is not compromised and it is possible to efficiently remove arrays during roof work. However, these mounts are primarily suitable for metal roofs. In the case of built-up, concrete roofs, weighted concrete pads can be used to help secure arrays, but not all roof surfaces or structural support arrangements may be amenable to this approach. During the site visit, a number of buildings potentially suitable for building integrated PV were identified and documented in Table 13, which provides approximate building roof areas and potential array capacities[7] and energy outputs.

[7] Array capacities calculations assume that 50% of the roof space will be available for an array. Some roof space must remain open to account for spacing around parapet walls, HVAC units, ventilation equipment, penthouses, other equipment/features, and to preserve walkways for maintenance and fire suppression purposes.

Table 13: Building-Integrated PV Array Details

Building Number	Roof Area	Available Area for an Array	Array Size and Output, MW/MWh[8]	Miscellaneous Notes
89010	215,500 sf	108,000 sf	1.9MW/ 2,660 MWh	Flat roof with minimal amounts of roof equipment or protrusions.
1001	90,000 sf	45,000 sf	0.8MW/ 1,110 MWh	Flat roof. Complex roof shape with skylights, HVAC units, HVAC pipe runs, parapet walls, and other structures.
28000	46,000 sf	23,000 sf	0.40 MW/ 570 MWh	Flat roof. Somewhat complex roof shape. Roof feature on south edge of roof results in moderate shading. Tapered building shape may complicate optimal array layout.
49015	40,000 sf	20,000 sf	0.35 MW/ 490 MWh	Flat roof with minimal amounts of roof equipment or protrusions. Vents along the roof centerline.

Lastly, large and expansive carports or shading structures are often suitable for integrated PV systems as well, as these structures can offer simple and low-cost construction sites, and the fear of roof penetrations and warranty complications can be reduced or removed entirely.

Economics

PV module prices are currently in rapid decline (PV Magazine 2011) and have dropped in price by approximately 55% since 2002 (SolarBuzz 2011). Consequently, each case was evaluated with a high and low system price to reflect the current price of modules and the anticipated price of modules in the near future. Monocrystalline silicon PV modules are assumed for this analysis. Furthermore, as larger PV arrays are developed, greater economies of scale are being realized, and arrays in excess of 20 to 30 MW have notably lower cost per installed watt than arrays ranging from 1 to 20 MW.

Solar PV arrays are not capable of providing baseload power because of the intermittent nature of solar energy (i.e., day-night cycles, cloud cover). Furthermore, PV arrays may only have a limited impact on peak demand periods because of the mismatch between peak array output, which occurs around noon, and a site's peak demand period, which typically occurs in the afternoon. Consequently, PV arrays may, and likely will, displace only a portion of the demand charge relative to the array's rated capacity. Complications such as ratchets and time-of-use conditions can further affect the value of the power produced by the array. To accurately estimate the value of the power produced by an array, a careful analysis must be conducted of an

[8] Note, output estimates assume the capacity factor calculated for the flat roof scenario. Furthermore, install densities and estimates rely upon module and array assumptions (e.g., module efficiency) documented in this analysis.

array's annual output and the site's demand profile, and it must also account for time-of-use rates, ratchets, and other conditions that affect demand charges. A conservative approach is to assume that an array only displaces electricity charges and not power charges. This charge is known as the marginal electric rate; the marginal electric rate at Fort Hood is 4.3¢/kWh.

Table 14: Economic Assumptions and Results for Solar PV Arrays at Fort Hood

	Ground-Mounted Fixed-Tilt PV Array		Ground-Mounted Single-Axis Tracking PV Array		Roof-Mounted PV Array	
MACRS Federal Depreciation	Included		Included		Included	
Federal Tax Rate	35%		35%		35%	
Federal Energy Tax Credit	30%		30%		30%	
State Energy Tax Credit	10%		10%		10%	
Cost Case	***Low***	***High***	***Low***	***High***	***Low***	***High***
Capacity Factor	17.1%	17.1%	21.5%	21.5%	16.3%	16.3%
Array Output, MWh/MW	1,502	1,502	1,881	1,881	1,430	1,430
Module Efficiency	18.5%	18.5%	18.5%	18.5%	18.5%	18.5%
Plant Life, yrs	20	20	20	20	20	20
Equipment Cost, $/kW	$3,500	$4,500	$4,000	$5,000	$3,250	$4,250
Variable O&M, $/kWh	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fixed O&M, $/kW	$20	$20	$33	$33	$20	$20
SIR	0.21	0.16	0.23	0.18	0.19	0.14
Simple Payback, yrs	72	93	66	82	80	104
IPP Case: Cost of Electricity at 10% IRR	21.5 ¢/kWh	27.6 ¢/kWh	19.6 ¢/kWh	24.4 ¢/kWh	23.7 ¢/kWh	30.9 ¢/kWh
Value of Displaced Electricity	4.3 ¢/kWh	4.3 ¢/kWh	4.3 ¢/kWh	4.3 ¢/kWh	4.3 ¢/kWh	4.3 ¢/kWh
REC Sales Price Point to Breakeven	17.2 ¢/kWh	23.3 ¢/kWh	15.3 ¢/kWh	20.1 ¢/kWh	19.4 ¢/kWh	26.6 ¢/kWh
Maximum Value of RECs in State	5.0 ¢/kWh	5.0 ¢/kWh	5.0 ¢/kWh	5.0 ¢/kWh	5.0 ¢/kWh	5.0 ¢/kWh

At this time, none of the systems considered is cost-competitive, although the single-axis tracking system proved to be the most economically competitive with an SIR of 0.23 in the low capital cost scenario. In the event of third-party array ownership, the single-axis tracking array could produce electricity that would cost 19.6¢/kWh, which is above both the marginal electric rate and the blended electric rate (i.e., even if the array could displace 100% of the demand charges, it would not be cost-effective).

The combination of the low cost of the displaced energy, moderately high system costs, and a limited renewable energy certificate (REC) market is the primary barrier to economic solar power development. Specifically, although the state has a renewable portfolio standard (RPS) that slightly favors non-wind RECs, the REC market is saturated, and the RPS establishes a non-compliance/alternative compliance penalty of 5.0¢/kWh (DSIRE 2011c) in the event that a utility fails to meet the RPS mandated REC procurement level. Non-compliance penalties effectively cap the price for RECs as it is more economic for a utility to pay the penalty than to purchase RECs more costly than 5.0¢/kWh. More discussion on RECs in included in the Regulatory Framework for Renewable Energy Project Development section below.

Project Sizing

Like the wind economic analysis, the solar economic analysis is also performed on a per–kilowatt-installed basis, so project size is scalable. To determine an exact potential project size, the RE goals detailed previously provided the parameters. Table 15 demonstrates what it would require to meet these goals with solar energy projects, based on the estimated capacity factors and energy productions of the evaluated arrays.

Table 15: RE Goals and PV Array Contribution

FY10 Electricity Consumption	**FY10 Energy Consumption**	**Electricity Required to meet 7.5% of 2013 Electricity Consumption (EPAct Requirement)**	**Energy Required to meet 25% of 2025 Energy Consumption (DOD goal)**
461,246 MWh	813,555 MWh	34,593 MWh	203,289 MWh
PV Array Case		**Project Size to Meet Requirement**	**Project Size to Meet Requirement**
Ground-Mounted Fixed-Tilt PV Array		23 MW	135 MW
Ground-Mounted Axis Tracking PV Array		18 MW	108 MW
Roof-Mounted PV Array		24 MW	142 MW

Given that 1 MW of solar PV panels can require 3 to 5 acres of space, it is unlikely that Fort Hood will be able to secure approximately 700 acres for a solar installation large enough to meet its DOD RE goal. It is more likely that Fort Hood will pursue roof-top solar projects that have less impact on land use, but will not generate large amounts of electricity.

Landfill Gas

Energy generation from landfill gas is highly dependent on site-specific environmental and economic conditions.

Resource and Siting

There are no sources of landfill gas on or near Fort Hood that could be used for energy generation. Fort Hood has an onsite landfill that is claimed to not release any methane; it is tested biannually. The landfill has many characteristics that are typically indicative of promising methane release, but the total amount of waste in place is only about 85% of what is typically needed for sufficient methane generation for electricity production. Therefore, it is expected that the landfill would have insufficient landfill gas for a project, but it is unclear why *no* methane is currently being detected, especially given past data. The 2008 analysis of landfill gas potential indicated the following (Chvala et. al. 2008):

> There are no methane collection requirements for this region, so the closed cell is only vented through four vents. One of the vents has a pipe system to the bottom of the cell due to a previous methane leak investigation. These vents currently release approximately 140,000 kcf of methane per year, with a modeled maximum potential of 153,000 kcf per year to be reached in 2071. About 60-80% of this could be recoverable, resulting in less than 1 MW of electricity production in the near future, and just over 1 MW at the maximum. This is not a large enough project to be considered for development.

There are 33 landfill gas projects in Texas according to the Landfill Methane Outreach Program (LMOP) database (LMOP 2011). All except one are located on the eastern side of the state, which is more humid and receives more rainfall than the western part of the state. (Fort Hood is located in the central part of the state, but within the more humid climate zone.) Moisture is important for efficient breakdown of waste and the resulting methane generation.

Projects produce both electricity and gas for direct use. Electricity generation projects range from 1.6 MW to 10.0 MW in capacity. The landfills range in size from 2.2 million tons of waste in place to 30.0 million tons of waste in place. These are all larger than Fort Hood's maximum permitted landfill capacity of 1.8 million tons of waste.

The expected production of landfill gas is dependent on a continuous, consistent stream of waste being deposited in the landfill. Once the landfill is closed, the methane production will begin to decline after a couple of years. There is a high probability that with Fort Hood's net-zero waste efforts, the amount of waste deposited in the landfill will steadily decline and eventually the landfill will no longer be used. Lack of additional waste will significantly decrease the amount of landfill gas production, if it is producing any now. Because of the lack of methane found at the landfill currently, the low production expected throughout the landfill life, and the expected decline in use of the landfill, it is not recommended for Fort Hood to pursue a landfill gas project at the installation landfill.

The nearest offsite landfill to Fort Hood, Temple Landfill, is about 10 miles away, which is too far for economic transportation of the landfill gas. Cost-effective electricity generation could not be established on Fort Hood using gas from Temple Landfill. Therefore, it is not recommended for Fort Hood to pursue any landfill gas energy projects.

Economics

The 2008 analysis was based on a model of annual waste deposits in the landfill and the methane generation amounts detected at the time. A continuation of this analysis (including current and future waste deposits) shows that the prediction is still similar; if methane were found to be released from the Fort Hood landfill, only about 1.2 MW could be generated at peak gas flows. A project this small is rarely cost-effective, and because there are no gas collection systems currently installed, capital costs will be even higher. Total project costs would be about $2.9 million, and generated electricity would need to cost almost 11.0¢/kWh to produce a 10% IRR.

Shale Gas

Like landfill gas, energy generation from shale gas is highly dependent on site-specific environmental and economic conditions.

Resource and Siting

Shale gas is natural gas produced from a geologic formation known as shale. Shale is a fine-grained sedimentary rock that forms by compaction of an organic-rich mud-like substance that over geologic time may become rich in natural gas and petroleum. The fine-grained nature of shale makes these formations "tight" and therefore difficult to extract the trapped gas. However, new technologies such as artificial fracturing (hydrofracing) and horizontal drilling have made it possible to extract large quantities of gas from shale formations, making shale gas an increasingly popular fuel source.

In the vicinity of Fort Hood, the Barnett Shale Formation is the primary source rock for oil and gas production and is among the most significant gas producing formations in Texas (Pollastro 2007). Although the Barnett Shale is present beneath Fort Hood, as shown in Figure 7, successful gas production from the Barnett Shale is limited to areas that satisfy a unique set of geologic conditions that are not present beneath Fort Hood. Consequently, shale gas production is not a feasible option at Fort Hood.

The viability of the Barnett shale as a successful gas reservoir is controlled by a number of limiting factors such as reservoir thickness, depth, geochemistry, and the geologic properties of the confining rock formations. The following section provides a brief summary of the geologic conditions beneath Fort Hood and how it compares to successful gas producing regions located to the north.

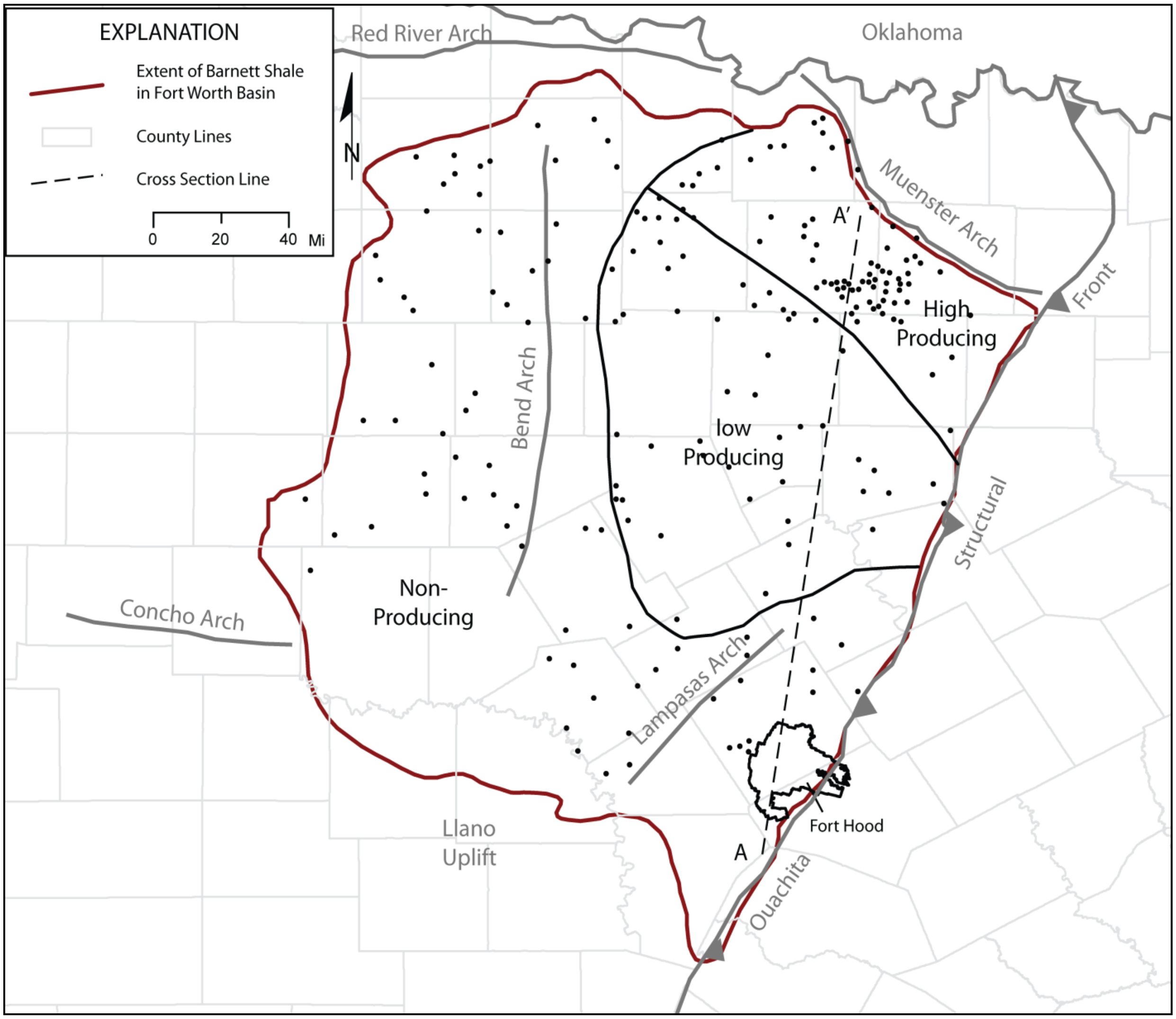

Figure 7: Location map showing the extent of the Barnett shale and structures that border the Bend Arch-Fort Worth Basin

Geology of the Barnett Shale in the Vicinity of Fort Hood

The Barnett Shale is located in the Bend Arch-Fort Worth Basin Province of north central Texas (Figure 7), where several major structural features confine the basin to an area covering approximately 54,000 square miles. After deposition of the Barnett Shale (354-323 million years ago), the Llano Uplift (318-271 million years ago) uplifted Precambian age rocks along the southern boundary of the basin. This resulted in general thinning and shallowing of the Barnett Shale to the southwest where it outcrops at the surface in San Saba and Lampasas counties (see Llano Uplift in Figure 7).

Historical gas production from the Barnett Shale is limited to areas with a shale thickness of at least 100 feet, but low production shale typically requires a thickness greater than 300 feet and high production shale requires a thickness between 500 and 1,000 feet (Pollastro 2007). The strong correlation between shale thickness and gas production is illustrated in Figure 8, which shows Fort Hood located well to the south of the successful gas producing area of the Barnett Shale. Well data indicate that the Barnett Shale beneath Fort Hood is approximately 35 ft thick and occurs at depths approximately 3,300 to 4,800 feet below ground surface (thickness and depth estimated from maps in Pollastro's 2007 study).

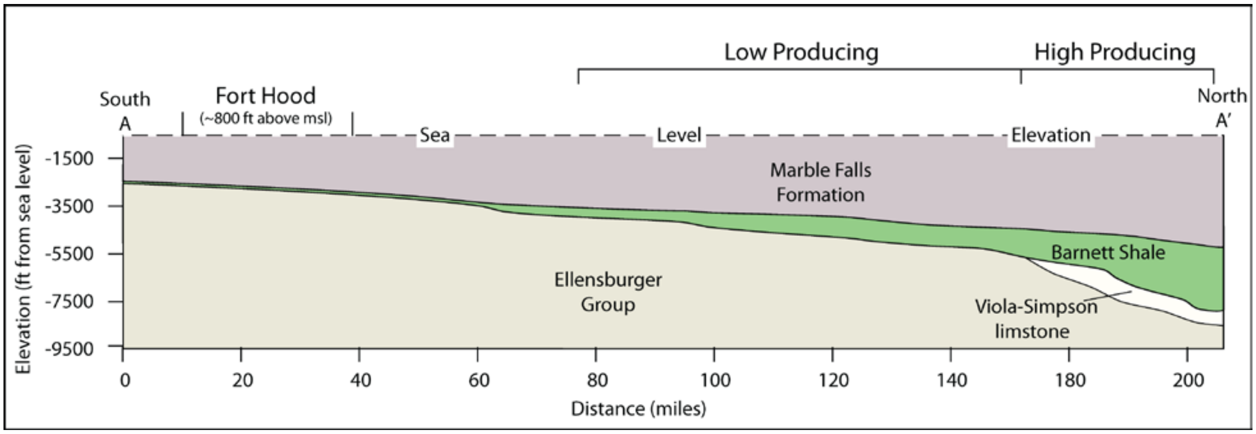

Figure 8: Cross-section showing the southward thinning of the Barnett Shale and the location of the core gas production area with respect to the thickness of the Barnett Shale. Cross-section modified using data from a structure contour map and an isopach (thickness) map of the Barnett Shale (Pollastro 2007).

The Barnett Shale is generally very "tight" with very low natural gas flow and therefore requires stimulation by fracturing to obtain commercially economic gas production (Gonzalez 2005). During early production of the Barnett Shale, the stimulation technology required the presence of a well-consolidated low permeability rock to act as a fracture barrier above and below the shale to contain the high pressures induced during hydraulic stimulation activities (Barlow 2007). Limestone rocks such as the Marble Falls and Viola-Simpson Limestone formations have proven to be effective fracture barriers, resulting in greater exploration and gas production of the Barnett Shale in areas where both limestone formations are present (see high production area in Figure 8). The presence of the underlying Viola-Simpson Limestone is especially important as it provides a barrier to the underlying Ellenburger Group, which consists of more permeable water bearing limestone that may become hydraulically connected with the Barnett Shale and limit gas production. The absence of the Viola-Simpson Limestone coupled with the thinness of the Barnett Shale beneath Fort Hood, as shown in Figure 8, presents a high probability of hydraulic stimulation opening fractures into the Ellensburger Group.

Although gas production is still concentrated in areas where the Viola-Simpson Limestone is present, the necessity for the limestone barriers has been reduced with the advent of horizontal drilling technologies (Gonzalez 2005). Horizontal drilling allows for less aggressive fracturing techniques, which enabled the expansion of the gas field to include a relatively lower production area within thinner (100-300 feet thick) sections of the Barnett Shale (Figure 8). However, this expansion area does not extend to the very thin (35-45 feet) portions of the Barnett Shale as it exists at Fort Hood.

Economics

Based on existing data, the geologic conditions that define a productive shale gas resource are not present at Fort Hood. An economic assessment was not performed because shale gas production is not a feasible option at Fort Hood. Fort Hood should not pursue on-site shale gas production further; however, if new exploration and development techniques become available, Fort Hood should entertain exploration proposals, if there is legitimate industry interest.

Regulatory Framework for Renewable Energy Project Development

Legislative and agency mandates and goals direct facility managers to develop renewable energy projects and/or displace conventional energy sources with renewables to enhance energy security and reliability, to increase the fraction of energy provided by renewable resources, and to reduce greenhouse gas (GHG) emissions. Renewable energy projects located on site are eligible for a "double" credit from the U.S. Department of Energy (DOE) towards Federal agency renewable energy goals. Because of resource and land availability restrictions and regulations surrounding power generation, transmission, and consumption, developing renewable energy on Federal land is complex.

Texas is a partially deregulated state. Most of the areas in Texas that are without electric competition are those served by municipal utilities or electric cooperatives. Other areas do not have a competitive retail market because the Public Utility Commission of Texas has determined that there is not enough competition in the wholesale market to support a successful retail market (TEC 2011).

Because of this deregulation, Fort Hood has been able to contract with multiple retail electricity providers (REP) over the years. At the time of PNNL's 2008 RE assessment for Fort Hood, Constellation Energy was the installation's REP. After that, TXU was under contract through the end of 2010. Reliant Energy is the current REP. Fort Hood entered into a two-year contract with Reliant in January 2011.

Reliant Energy is a part of NRG Energy, a large buyer and generator of electricity which owns 26,000 net MW of generation capacity with 2% of this being renewable (Reliant 2011).

Distributed renewable energy generators may sell excess power to their REP, similar to a net metering program for small systems. A generator is only allowed to sell its excess power to its REP, but REPs are not required to purchase this power. Reliant Energy only offers buyback programs for residential, school and small business customers (TEC 2011) and therefore this type of arrangement is not available to Fort Hood, nor is it likely to be of interest to the installation.

In 1999, the Public Utility Commission of Texas (PUCT) established a renewable portfolio standard (RPS), a renewable energy certificate (REC) trading program, and renewable energy purchase requirements for competitive retailers in Texas. The current amended RPS requires 5,880 MW by 2015 (with each retailer allocated a share of this requirement), 500 MW of which must be non-wind, and an additional goal of 10,000 MW by 2025 (DSIRE 2011c). Both goals have already been surpassed. According to the PUCT, there were 10,256 MW of renewable energy projects installed in Texas as of December 31, 2010 (PUCT 2011). MSW is not considered a renewable resource under Texas RPS rules.

To address concerns about the adequacy of the state's transmission systems, the PUCT also requires utilities to add to their transmission systems to meet the renewable energy goal, and to allow utilities to recover the cost of such projects in their electric rates (DSIRE 2011c).

To provide additional incentive for non-wind renewable generation, non-wind RECs receive a premium that essentially doubles the REC value (DSIRE 2011c). One REC represents one megawatt-hour (MWh) of qualified renewable energy that is generated and metered in Texas. The non-compliance penalty is $50 per MWh for providers who do not meet the RPS requirements (DSIRE 2011c). The Texas REC market is operated by the Electric Reliability Council of Texas (ERCOT).

Incentives

The state of Texas offers a 10% franchise tax deduction on solar and wind energy systems (DSIRE 2011a) and a property tax exemption for renewable energy systems (DSIRE 2011b).

Besides its limited buyback programs, as a competitive REP, Reliant Energy does not provide any renewable energy incentives and relies primarily on annual REC purchases from the ERCOT REC market to meet its RPS requirements.

Development Options

Fort Hood’s best option to develop a large-scale project is to use a third-party developer: either a retail electricity provider, such as Reliant Energy, or an independent power producer (IPP).

A third-party developer would engineer, finance, construct, own, and operate the RE facility. The installation would then purchase the RE directly from the developer through a power purchase agreement (PPA). Because Fort Hood is in a deregulated jurisdiction of Texas, it is not required to purchase electricity from a specified local service provider.

In addition to the benefits of having a third party with specialized expertise in the design, development, and operation of a resource, third-party developers often have access to many state and Federal incentives that enable a project to be more cost-effective. These incentives may include production tax credits, investment tax credits, substantially accelerated tax depreciation of assets, reductions in sales taxes, and exemption from property tax. These tax-based incentives are only available to non-government, taxable entities. Use of these incentives can reduce the cost of a project by as much half compared to one developed using appropriations.

ECIP funding is available on an annual basis, and ECIP funds are relatively easy to obtain because the program accepts renewable energy projects with SIRs as low as 1.0. Projects with low SIRs are likely to be unattractive to most third-party financiers as these projects will likely have an unacceptably low rate of return. Therefore, ECIP may be the only major means of financing such projects. ECIP is now encouraging projects, especially renewables, valued at $5 million and larger. However, ECIP projects are typically still on the small scale, especially because they result in government ownership, which is not desirable for large-scale projects. ECIP is appropriate for projects such as solar air or water heating, ground source heat pumps, roof-mounted PV, or other small-scale renewable energy and energy efficiency applications.

Table 16 details some of the pros and cons of the development options available to Fort Hood.

Table 16: Development Options – Pros and Cons

Development Option	Pros	Cons
Off-site project, third party owned and operated	Land off site may be more suitable. Private transmission could bring power to site.	Don't get credit for being on site. Doesn't provide same level of energy security.
On-site project, third party owned and operated	Credit for having project on site. May provide energy security.	Must have space and resource availability on site with minimal training and mission conflicts.
On-site project, Fort Hood owned and operated	Small projects, such as rooftop solar PV, are reasonable ECIP-funded projects	Not recommended for large-scale projects (not compatible with DOD's mission). Army cannot take advantage of any tax-based incentives.

The project development options described above must also consider economic implications that are not captured in the economic analyses provided in this assessment. It may be less expensive to develop a project off-site, for example where the wind resource is stronger, but the additional cost of transmission to bring the electricity to Fort Hood must then also be considered. Alternatively, a higher cost on-site project may be justified by non-quantifiable benefits: the energy security it could provide, the double credit it would receive with respect to RE goals, and the opportunity to be a RE leader among Army installations.

The Army tends to focus on procurement of the lowest-cost energy that meets high reliability standards and minimum vulnerability to interruption from natural or intentional causes. Overlaid on this challenge is the need to comply with RE generation, energy efficiency (EE), and greenhouse gas (GHG) emission reduction goals and mandates set by the Federal government, the DOD, and the Army.

Because many on-site RE projects at Army installations have marginal economics when evaluated, and many Army installations currently enjoy low costs of energy, RE projects on Army installations are not being developed at the rate needed to achieve the Federal, DOD, and Army RE and GHG goals and mandates. This leaves installations delaying the implementation of on-site projects with the hope that economics will improve in the near future because of reduced project costs or higher electricity rates. Army policy does allow installations to pay an appropriate premium for renewable energy and Congress requires purchases that are life-cycle cost effective, however no guidance has been offered to date. With the new Army Energy Initiative Task Force (EITF), it is hoped such guidance will be forthcoming.

With respect to RE project development for Fort Hood, the best options for each resource are described below. In addition, a regional development approach is described. This unique approach addresses the economic barrier on-site RE development faces on Army and other DOD installations.

Wind

The best development option for a wind project for Fort Hood, either on-site or off-site, is to obtain a PPA for a project developed, owned, and operated by a third party.

EDP Renewables' Gatesville Wind Farm (described in detail in the Market Conditions section) is one possible project from which Fort Hood could purchase wind energy. The energy could be purchased through a traditional PPA, or a private transmission line (assuming land right of ways can be obtained) could bring the electricity directly to Fort Hood. A private transmission line would increase the capital cost of the project significantly and is not included in the economic analysis of this report. Wheeling the power over existing transmission lines is another option. Wheeling over utility transmission lines is more conventional, and is likely to cost less than a new transmission line, but it presents other challenges. First, the most direct transmission path circles the base rather than cutting through it. Second, transmission costs vary depending on line loadings. The addition of new wind on these lines could significantly increase wheeling costs.

EDP Renewables is open to talking with Fort Hood about the installation being an off-taker for its Gatesville project and would also be interested in talking about any on-site development Fort Hood is considering. Because the off-site project is still under development, EDP Renewables has indicated that the project size can be adjusted to meet the off-taker's needs. For example, while the project size currently being considered is 100 MW, they would consider making it smaller if that better met Fort Hood's needs. As described previously, a 14 MW project would be required to meet the 7.5% EPAct mandate and an 80 MW project would be required to meet the 25% DOD goal.

Municipal Solid Waste

A large-scale MSW plant, whether combustion or gasification, should be developed by a third-party IPP with prior experience. An onsite project would require a request for proposals to choose the appropriate development partner. A gasification plant is not likely to be developed in the near future because of the lack of existing commercial plants, and therefore partners with experience, in the U.S.

If a large onsite plant conflicts with the Army's net-zero waste goals and Fort Hood's environmental policies, Fort Hood should work with regional entities to explore the opportunity for WTE in the area. If there is interest, an IPP selected through a competitive procurement would take the lead in seeking project partners for supply of MSW and sale of electricity. The local landfill may be interested if economics are favorable. If economics are not favorable for a regional project, it is unlikely to be developed because there is sufficient landfill space in the area and Austin's net-zero waste goal is not supportive of the technology. If developed, an offsite project may not be able to deliver electricity to Fort Hood, but it could help Fort Hood meet their net-zero waste goals.

It may become necessary for Fort Hood to meet its net-zero waste goals by developing a small-scale MSW gasification plant with appropriated funds. If the economics are favorable, ECIP funds could be used, but that is unlikely. It is more likely the Army will need to pay for the project out of operating funds and use it for demonstration purposes.

Solar PV

The best development option for a large solar array at Fort Hood, either on-site or off-site, is to obtain a PPA for a project developed, owned, and operated by a third party. Smaller arrays may be funded via ECIP or other similar funding avenues. If the site is interested in developing a large-scale array, it should issue a request for information (RFI) to gauge local developer interest and to review current economic parameters. The RFI should include a forecast of expected future power costs so that industry can respond appropriately. For example, projected costs may be too low for an economic project, but industry may be able to identify future conditions where it would be, such as new incentive proposals or lower future PV costs.

Regional Development Approach: Texas Renewable Exchange

Each federal agency has obligations to comply with federal mandates and voluntary goals to increase the use of renewable energy and reduce its GHG emissions. All agencies are bound by Congressional and Executive Order mandates and some, such as DOD, have adopted more ambitious goals.

Progress towards these goals has been complicated for a variety of reasons, although the biggest barrier is the higher cost of renewable power. For example, in an effort to provide Joint Base Lewis-McChord with a strategy to become net zero, PNNL evaluated renewable resources available on land managed by the base. Although adequate resources are available, the scale of development required to reduce the resulting power costs presented challenges to the military mission. This led to the conclusion that the most economic strategy for meeting federal renewable and GHG goals would be to exploit the *economies of scale* inherent in many renewable resource projects by developing projects on *idle Federal lands* with resources that could support large-scale projects. The key to success is developing projects that are large enough to reduce costs. However, projects this large typically exceed the renewable energy and GHG goals of any one Federal facility. As a result they need to be jointly developed to meet the needs of multiple Federal facilities. More importantly, some regions can provide renewable resources at a cost that is lower than other regions. Therefore it makes economic sense to purchase power from regions with the lowest cost than it does to do so where the cost is higher.

From these discussions with Joint Base Lewis-McChord, the Northwest Energy Initiative (NWEI) was born. It has been proposed as a model for regional cooperation by the Army's EITF as well as the DOE Asset Revitalization Initiative (ARI). It is built on elements that can be adapted to region-specific situations (contracting capabilities, local utility environment, resource availability, energy costs, etc.).

It was natural for the NWEI to emerge from the northwest because it is a region with abundant renewable energy resources that are being actively developed to meet the needs of utilities locally as well as in California. Although these resources serve retail utilities, not retail customers, the institutional environment can facilitate retail customer transactions due to the presence of the Bonneville Power Administration (BPA). Somewhat similar conditions exist in Texas as power can be provided from renewable energy projects directly to retail customers in deregulated jurisdictions. Therefore PNNL recommends a similar program for DOD facilities in Texas, a Texas Renewable EXchange (TREX).

There are multiple Army, Air Force, Navy, and other Federal facilities in Texas. Texas has abundant wind and solar resources that can meet the RE goals of these facilities and joint development can reduce the cost of doing so for all sites. Also, the Texas transmission system allows for power to be delivered directly to customers, which facilitates joint development of a project and allows a project anywhere in Texas to be used to meet various facilities' RE and GHG goals.

PNNL previously worked with DOD, DOE, and GSA facilities in Texas on a joint renewable energy procurement strategy. That market wasn't mature at the time, but it is now, making it reasonable to assume both GSA and DOE would be willing partners in TREX since their renewable development options are more limited.

Market Conditions

There are many existing RE projects and RE development activity in Texas, predominately wind with some biomass projects. The Public Utility Commission of Texas keeps a list of Electric Generating Plants in Texas since 1995 on its website (PUCT 2011). Existing and proposed renewable projects are shown in Figure 9.

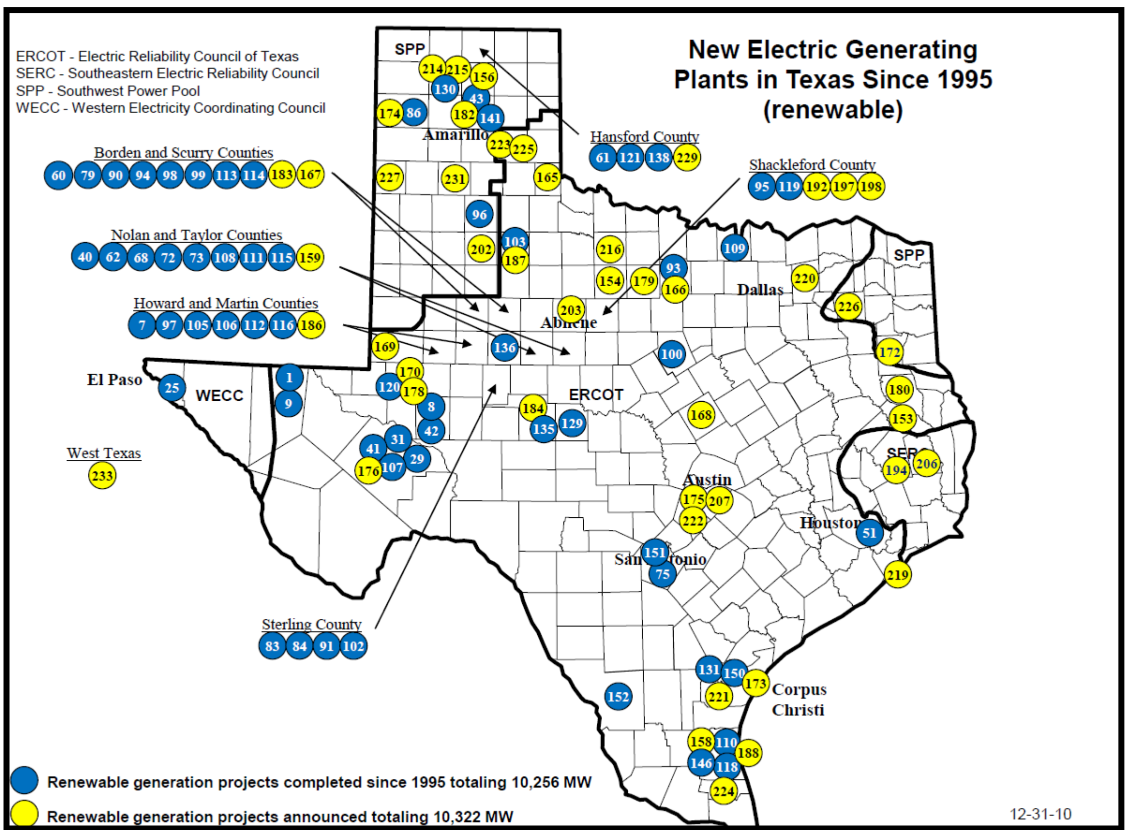

Figure 9: Map of State Renewable Energy Projects (PUCT 2011)

Wind

Project 168 in Figure 9 is in Coryell County, the county in which most of Fort Hood's training land is. Bell County, where Fort Hood's main base is located, is the county directly southeast of Project 168. On the PUCT website, Project 168 is listed a 200-MW wind project under development and scheduled to be operational December 2011. This is EDP Renewables' (formerly Horizon) Gatesville Wind Farm mentioned in PNNL's original RE assessment (Chvala et al. 2008).

PNNL contacted Kris Cheney, the Gatesville Wind Farm project manager, to learn about the current status of the project (Orrell 2011). EDP Renewables is continuing development of the project by renewing its land licenses and pursuing additional land licenses. The project has 13,000 acres secured and would like to have 15,000 to 16,000 acres. While the project was originally intended to be 200 MW, the company is now focusing on developing a 100 MW project on land in a more concentrated area. The secured land is located in an area with a higher wind resource than Fort Hood's. While Fort Hood's wind resource averages 6.0 – 7.0 m/s at 80 m, the Gatesville site has 7.0 – 7.5 m/s at 80 m winds. This higher wind resource will increase the project's energy production potential and thus allow it to have more favorable economic conditions, compared to a project on Fort Hood.

The December 2011 operational date on the PUCT website is based on EDP Renewables' original interconnection request filing made in 2008. The company has informed the Electric Reliability Council of Texas (ERCOT) that the earliest the project could interconnect is now 2013.

The project does not currently have a PPA, but needs one to go forward. The company does not believe the alternative, selling power as a merchant power producer, is viable for this project as merchant power prices are very low at this time.

The strongest wind resources in Texas are located in the western half of the state, and thus so are the majority of the state's wind projects. Because there are transmission constraints in bringing that energy from the west to the load centers in the east, new wind energy project development in west Texas has currently stopped. ERCOT operates a nodal pricing market. In west Texas, where there are fewer load centers, the nodal pricing is lower than in the eastern and central parts of Texas. So while the wind resource is not as strong in the Gatesville area as it is in west Texas, EDP Renewables believes the nodal pricing market conditions provide an advantage for its potential wind project.

When the new Competitive Renewable Energy Zone (CREZ)[9] transmission lines are completed in 2013, transmission constraints should no longer be an issue and development in west Texas and the panhandle should resume. This additional supply could lower pricing in the higher priced eastern load centers.

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[9] Based on wind data and transmission cost calculations, ERCOT designated five CREZs and authorized the construction of 2,400 miles of new transmission lines to support these zones (ETT 2011 and SECO 2011).

Municipal Solid Waste

There are currently no WTE facilities operating in Texas. Some small-scale facilities are under development, and one has been proposed at Dyess Air Force Base. However, because Texas currently does not consider WTE renewable, has sufficient landfill capacity, and has land to expand capacity in many areas, there is little current interest in this technology. One area that has considered it is the Rio Grande Valley in southern Texas (Janes 2009), but development interest near Fort Hood is limited. In fact, the City of Austin has an explicit goal to avoid incineration of MSW.

Solar PV

PV development has been modest in Texas. As of 2010, nearly 35 MW of solar PV arrays have been developed (IREC 2011). This installed capacity is significantly smaller than California's 1,000 MW, New Jersey's 259 MW, Colorado's 121 MW, Nevada's 104 MW, Florida's 74 MW, and Massachusetts's 38 MW. The difference in solar PV array development in other states is not strictly driven by resource availability, but by state policy, RPS requirements, and high penalties for not achieving RPS-mandated renewable energy generation.

Recent and planned projects in Texas include:

- 14-MW, thin film, fixed axis PV array near San Antonio (CPS Energy 2011), and
- 30-MW PV single-axis array planned for construction over 2011 (Sustainable Business 2011).

These arrays employ a range of mounting and module technologies, suggesting that no one approach or technology is the most suitable for Texas or Fort Hood.

Environmental Review and Impacts

There is known habitat on Fort Hood for two federally-listed endangered species: the black capped vireo, a ground-nesting bird, and the golden cheeked warbler. Whooping cranes, another federally-listed endangered species, visit Fort Hood annually for a short period of time. In addition, the Texas horned lizard can be found on Fort Hood and is a state-listed threatened species.

Endangered species core habitat areas are clearly marked on Fort Hood's Military Installation Map and cannot be disturbed. These areas are located along the eastern border of the installation on the shores of Belton Lake.

Any construction in the main cantonment area would have fewer obstacles than construction in the training areas. In addition to mission conflicts, the training areas have more vegetation and trees that Fort Hood works to protect.

Water concerns at the installation are minimal. Availability for a WTE project or for cleaning solar PV panels is not an issue as Fort Hood has the rights to 12,000 acre-feet and typically uses only 8,000 acre-feet (Orrell 2011b).

Other resource-specific concerns are described below in the respective sections.

Wind

The main environmental concerns with wind energy projects are typically turbine height, land impact, noise, and wildlife impact.

Commercial-scale wind turbines can have tip heights (i.e., the highest point of a turbine is the tip of its vertical turbine blade) of 400 feet (~120 m) and above. Because wind speeds are higher at higher elevations, turbines hub heights are also high, but height restrictions may be imposed to mitigate visual impact concerns, radar interference, and interference with airport operations.

The land required for a single utility-scale wind turbine is typically 3 acres, including access roads, turbine base, and balance of plant equipment. The proper spacing of multiple turbines to create a wind farm is essential to reduce wake interference amongst the turbines and to optimize the wind resource. In open flat terrain, a utility-scale wind plant can require 20-60 acres per MW of installed capacity to allow for sufficient space between turbines and setbacks from road, buildings, and other structures.

Whether or not noise is an issue is typically dependent on the proximity of a wind farm to its neighbors. In a remote, windy location, turbine noise may not even be audible over the sound of the wind. Turbine manufacturers can provide sound power level predictions for their turbines. These predictions can be reviewed prior to purchasing and installing a turbine, and used in noise studies as necessary.

The U.S. Fish and Wildlife Service (USFWS) provides voluntary wind turbine guidelines (Wind Turbine Guidelines Advisory Committee 2010) to be used to avoid or minimize impacts to wildlife and their habitats related to land-based wind energy projects. Project location, rather than project size, can have a greater impact, so these guidelines should be consulted for any size wind project. Because of the endangered species on site, coordination with USFWS will be required. Mitigation efforts may include construction during non-breeding seasons or in areas where no breeding is occurring.

Municipal Solid Waste

Conversion of MSW in a WTE plant raises numerous environmental concerns. These can be mitigated to minimize the consequences for Fort Hood. For instance, different technologies result in significantly different levels of impact. The issues discussed here assume combustion is used; however, gasification greatly reduces emissions and hazardous waste products.

Emissions

The primary concern for a WTE plant is emissions. Currently Fort Hood is in attainment for all pollutants, but is being monitored for ozone. Non-attainment status requires state and local government to develop a plan to attain, and then maintain, air quality standards through reducing air pollutant emissions contributing to concentrations. Table 17 shows the primary pollutants of concern for WTE with standard pollution control equipment. Ozone is not a concern.

Table 17: WTE Pollutant Emissions Control Technologies

<table>
<tr><th>Pollutant</th><th>Applicable Pollutant Control Technologies[1,2]</th><th>Pollutant Removal Effectiveness Comments[1,2]</th></tr>
<tr><td>Dioxin/Furan (CDD/CDF)</td><td>Activated Carbon Injection (ACI) or Dry Sorbent Injection (DSI)</td><td rowspan="9">General Strategy: Pollutant removal is accomplished by a series of devices working in combination. Various technologies physically or chemically alter acid gases, heavy metals, and dioxins/furans so they can be captured by particulate matter (PM) control devices.

Typical Collection Efficiency of PM Control Devices:
CS: 90% collection efficiency @ 20 µm particle diameter
VS: 99% collection efficiency @ 5 µm particle diameter
ESP: 99% collection efficiency @ 0.05 µm particle diameter
FF: 99.9% collection efficiency @ 0.05 µm particle diameter

Additional Comments:
SNCR can reduce NO_x emissions by 45%, all else held equal.

Acid gases are neutralized via WS, SDA, or DSI to form salts, which are captured via ESP or FF. In recent years, SDA/FF systems have become favored over SDA/ESP systems due to more efficient removal of heavy metals.

Activated carbon injection into the flue gas stream can improve dioxin control by 75%, all else held equal.</td></tr>
<tr><td>Cadmium (Cd)</td><td>DSI or Spray Dryer Absorbers (SDA) (a.k.a. "dry scrubbing")</td></tr>
<tr><td>Lead (Pb)</td><td>DSI or SDA</td></tr>
<tr><td>Mercury (Hg)</td><td>ACI or DSI</td></tr>
<tr><td>Particulate Matter (PM)</td><td>Cyclone Separators (CS), Venturi Scrubbers (VS), Electrostatic Precipitators (ESP), Fabric Filters (FF) (a.k.a. "baghouses")</td></tr>
<tr><td>Hydrogen Chloride (HCl)</td><td>Wet Scrubbers (WS), SDA, DSI</td></tr>
<tr><td>Sulfur Dioxide (SO_2)</td><td>WS, SDA, DSI</td></tr>
<tr><td>Nitrogen Oxides (NO_X)</td><td>Selective Noncatalytic Reduction (SNCR): Injection of NH_3 or urea into furnace (most common method for NO_x control).

Selective Catalytic Reduction (SCR): Similar to SNCR but downstream of furnace and with a catalyst.

Combustion Controls (Temp or O_2 control to reduce NO_x formation): Refractory Furnace (no waterwall cooling), Staged Combustion, Low Excess Air, Flue Gas Recirculation</td></tr>
<tr><td>Carbon Monoxide (CO)</td><td>Combustion controls to help achieve complete combustion and downsream catalytic oxidation of remaining CO to CO_2 .</td></tr>
</table>

[1] Tchobanoglous, George and Frank Kreith. Handbook of Solid Waste Management, 2nd Edition. Chapter 13, Part 13C, Pages 13.132-13.154 Copyright 2002 McGraw-Hill. Retrieved from www.knovel.com

[2] EPA - U.S. Environmental Protection Agency, National Center for Environmental Assessment. An Inventory of Sources and Environmental Releases of Dioxin-Like Compounds in the United States for the Years 1987, 1995, and 2000. EPA/600/P-03/002F, November 2006. Pages 3-9,3-10.

All new MSW combustors defined as "large" by the EPA (processing ≥ 250 tons/day of MSW) are required to comply with the emissions limits listed in Table 18. (New "small" municipal waste combustors processing < 250 tons/day have equivalent or less-stringent limits.) As shown in Table 18, existing WTE facilities are well below these limits for the majority of pollutants. NO_x and CO are the pollutants closest to the Federal limits.

Table 18: Primary WTE Pollutants, Federal Emissions Limits, and Example U.S. WTE Facilities

Pollutant	Federal Emissions Limit for new MWCs[1]	Example Operational U.S. WTE Facilities	
		Wheelabrator Spokane[3,4] (Location: Spokane, WA) (Start-up: 1991; Size: 26 MW)	SEMASS Resource Recovery Facility[5] (Location: Rochester, MA) (Start-up: 1989; Size: 84 MW)
Dioxin/Furan (CDD/CDF)	13 ng/dscm	1.5 ng/dscm	0.9 ng/dscm
Cadmium (Cd)	10 µg/dscm	1.6 µg/dscm	1.2 µg/dscm
Lead (Pb)	140 µg/dscm	13 µg/dscm	30 µg/dscm
Mercury (Hg)	50 µg/dscm	5.3 µg/dscm	5.1 µg/dscm
Particulate Matter (PM)	20 mg/dscm	1.5 mg/dscm	4.6 mg/dscm
Hydrogen Chloride (HCl)	25 ppmdv	2.3 ppmdv	3.6 ppmdv
Sulfur Dioxide (SO_2)	30 ppmdv	3.2 ppmdv	16 ppmdv
Nitrogen Oxides (NO_X)	180 ppmdv (year 1) 150 ppmdv (after year 1)	135 ppmdv	141 ppmdv
Carbon Monoxide (CO)	100 ppmdv[2]	57 ppmdv	56 ppmdv

Units: ng = nanogram (10^{-9} g), µg = microgram (10^{-6} g), mg = milligram (10^{-3} g) dscm = dry standard cubic meter, ppmdv = parts per million dry volume

[1] Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Large Municipal Waste Combustors; Final Rule. Federal Register, Vol. 71, No. 90, May 10, 2006. The EPA considers a "large" municipal waste combustor (MWC) as one that processes greater than 250 tons/day.

[2] Varies from 50-250 according MWC technology; see "Table 3 to Subpart Cb of Part 60" in Reference 1. Most mass burn MWCs have a limit of 100 ppmdv, so this value is presented in the table. Modular MWCs (both starved and excess air) have a limit of 50 ppmdv, but they are mostly smaller MWCs.

[3] Performance Audit, Spokane Regional Solid Waste System, Section 4: Waste-to-Energy Facility Evaluation, Table 4-3 "Summary of Air Emission Testing, 2005-2008", page 4-17, July 2009. Values averaged for both combustion units over 2005-2008. Accessed at http://spokanewastetoenergy.com/WastetoEnergy.htm.

[4] Monthly Emissions Monitoring Reports for Spokane WTE Facility. Available from the Spokane Regional Clean Air Agency upon request. Values reported in table are averages of monthly maximum reported values for both combustion units over 2008-2010.

[5] Themelis, Nickolas J. "Table 3: Comparison of 1999 Emissions from SEMASS No. 3 Unit with EPA standards", Integrated Management of Solid Wastes for New York City, 10th North American Waste to Energy Conference, ASME 2002. Values averaged from 1994-1998 data for Boiler No. 3. Accessed at http://www.seas.columbia.edu/earth/wtert/sofos/nawtec/nawtec10/nawtec10-1007.pdf.

Failure to meet these limits can result in the following (EPA 2010):

- Violation corrected by facility without the need for enforcement actions. (The majority of violations are corrected this way.)
- Informal notice to facility that enforcement proceeding may occur if violation is not quickly resolved.
- Serious or continuing violations may warrant formal enforcement proceedings such as civil administrative or civil judicial actions. These actions can result in orders for steps needed to return the facility to compliance, fines, and supplemental environmental projects that a plant owner agrees to take as part of a settlement.

- Failure to comply with orders resulting from formal enforcement actions (e.g., failing to pay fines and take steps to reduce emissions) can result in a plant being shut down.

Permitting requirements for a new WTE facility are dependent on 1) the regional EPA office's designation of common control and 2) the total amount of emissions from the permitted source. The regional EPA office must make a determination of who has common control of the pollution-emitting process (WTE plant) and thus who is responsible (Fort Hood or the plant owner/operator) for emissions. This is determined with a test of three factors: who owns the facility; who is the primary beneficiary of the facility; and who makes decisions about facility operations. Common control has been determined both ways in previous cases, depending on the EPA district and specific project circumstances. Because the plant would be owned and operated by a third party, it is sometimes viewed as their permitting responsibility. However, if all or most generation is consumed on Fort Hood, EPA could determine that, as the primary beneficiary of the project, the installation is responsible for the plant's criteria pollutants. If the installation consumes the entire output of the plant, it is almost certain EPA will reach that conclusion. Accordingly, a conversation with the local EPA office would be needed to determine the responsible party.

If EPA determines that Fort Hood would be responsible, the installation's current emissions profile as determined under Title V of the Clean Air Act would need to be considered. The Clean Air Act designates a source as "major" at 100 tons/yr for an individual criteria pollutant (O_3, PM, CO, NO_x, SO_2, and Pb); 10 tons/yr for an individual hazardous air pollutant (HAP); or 25 tons/yr for all HAPs combined. Based on EPA data for existing WTE plants, Title V permitting is likely to be required for a WTE plant due to NO_x emissions exceeding the 100 tons/yr limit (EPA 2011, EPA 2010). WTE plants that are under the Title V threshold values do exist, but it is very likely that a WTE plant would put an installation over the limit when combined with other sources of air emissions (especially NO_x) onsite.

Currently, Fort Hood is a major source under Title V, although 2010 emissions were all within minor source limits. Total particulate matter in 2009 was above the threshold, although it was dramatically reduced in 2010. In 2010, carbon monoxide was the greatest pollutant at 85 tons/year. NO_x is generated at a consistent 31 tons/year (Fort Hood Air Quality Program 2011). See Table 19 for annual amounts of criteria pollutants/HAPs for three relatively small-sized operational MSW combustion plants. Gasification plants would generate fewer emissions.

Table 19: Required Title V Emissions Permitting Limits and Example U.S. WTE Facilities

	Pollutant	Maximum Limit for Required Title V Permitting	Example Operational U.S. WTE Facilities[1] Covanta Wallingford (Location: Wallingford, CT) (Start-up: 1989; Size: 11 MW)	Wheelabrator Claremont (Location: Claremont, NH) (Start-up: 1987; Size: 5 MW)	Covanta Pittsfield (Location: Pittsfield, MA) (Start-up: 1981; Size: ~ 9 MW[2])
Major Criteria Pollutants	Nitrogen Oxides (NO_X)	100 tons/yr	186 tons/yr	134 tons/yr	89 tons/yr
	Carbon Monoxide (CO)	100 tons/yr	13.7 tons/yr	5.3 tons/yr	6.0 tons/yr
	Sulfur Dioxide (SO_2)	100 tons/yr	3.0 tons/yr	52.5 tons/yr	0.7 tons/yr
	Particulate Matter (PM)	100 tons/yr	3.5 tons/yr	6.5 tons/yr	2.7 tons/yr
	Volatile Organic Compounds (VOC)	100 tons/yr	0.7 tons/yr	0.3 tons/yr	3.0 tons/yr
Hazardous Air Pollutants	Hydrogen Chloride (HCl)	10 tons/yr	9.4 tons/yr	23.5 tons/yr	1.2 tons/yr
	Total HAP	25 tons/yr	9.5 tons/yr	23.6 tons/yr	2.2 tons/yr

[1] U.S. EPA Enforcement & Compliance History Online (ECHO) Database, Clean Air Act. Accessed at http://www.epa-echo.gov/echo/compliance_report_air.html (last updated December 2, 2010). Annual emission tonnage amounts are from 2002.

[2] Covanta Pittsfield processes MSW at a rate of 240 tons/day or 84,000 tons/year, and generates steam as its output at a rated capacity of 68,000 lb steam per hour (http://www.covantaenergy.com/en/list-of-facilities/covanta-pittsfield/covanta-pittsfield-detailed.aspx). This amount of MSW could support a plant of approximately 9 MW if the final output was electricity instead of thermal energy.

GHG emissions generated from a third-party owned WTE plant are considered scope 2 emissions (indirect); therefore, emissions and generated power would be reported in conjunction with other electricity generating plants in the eGRID region. If Fort Hood were to purchase RECs from the plant, the associated emissions reductions would then be applicable towards the site's scope 2 emissions in accordance with the "Federal Greenhouse Gas Accounting and Reporting Guidance" (CEQ 2010). Distinguishing between fossil-based and biogenic carbon in MSW is important for evaluating the GHG emissions impacts of WTE. The biogenic carbon will not count towards a site's GHG inventory, while the fossil-based carbon will. A study of the waste stream used for feedstock will be necessary to determine the biogenic components.

Combustion or gasification of MSW in a WTE plant also results in avoided CO_2 emissions from electric utility generation and metals production (most WTE plants recover steel and other metals, reducing energy consumption and emissions compared with raw metals production). A thorough study of WTE life cycle emissions is presented in (EPA 2006). This report concluded that combustion of mixed MSW at WTE facilities reduces net GHG emissions by 0.02 to 0.03 metric tons of carbon equivalent per ton of waste combusted compared with a scenario in which the waste is landfilled (no metals recovery) and electricity is generated with the national average fossil fuel mix used by utilities. In practice, the type of fuel displaced is not always fossil; the majority of electricity generation in some regions is from cleaner sources (e.g., hydroelectric and nuclear), which will reduce the avoided utility CO_2. The net GHG emissions will also vary depending on waste stream composition (e.g., the fraction of fossil-based vs. biogenic waste).

Waste

A WTE facility provides an alternative to landfilling and captures stored chemical energy from material that would otherwise be discarded. Disposal of waste is a growing concern across the nation because landfills are filling up and disposal costs are rising. Near Fort Hood, landfill space is not a major concern at this time, but waste disposal and costs are still a consideration.

Contrary to many beliefs, a WTE facility does not compete with recycling. Data from a 2006 nationwide survey of MSW management in the U.S. showed that regions of the U.S. where WTE is most prevalent (New England and the Mid-Atlantic) also had higher-than-average recycling rates (Simmons et al. 2006). This positive correlation between WTE and recycling still holds true at the time of this report (van Haaren et al. 2010). Many recyclables are not beneficial in a WTE system; they cannot be turned into usable energy or they clog up the system. Feedstock preparation allows for separating and selling recyclables, thereby providing an additional revenue stream for the plant.

Ash generated from MSW combustion or gasification may be considered hazardous and require proper disposal. Combustion-generated ash volume is approximately 10% of incoming feedstock (approximately 25% by weight). Ash volume from gasification is somewhat less, and depending on the technology, could be a marketable product instead of a potentially hazardous waste. The size and type of the plant, therefore, will determine the amount of hazardous waste needing disposal.

MSW storage can be an issue for safety and health. An enclosed storage space will prevent attraction of birds or other wildlife that could pose a danger to aircraft or other operations. Enclosure will also prevent wind-blown dispersal of MSW into the base and surrounding environment, while also preventing possible creation of contaminated leachate generation from prolonged feedstock exposure to rain.

Water

A closed-loop cooling system would use approximately 300-480 gal/MWh (DOE 2006). Feedwater for a combustion boiler would also be required; assuming a condensate return rate of 95-98%, approximately 10-20 gal/MWh would be needed for boiler feedwater. Annual water requirements would therefore be about 90 – 146 million gallons for a 37-MW combustion plant. Gasification would require cooling water but not boiler water, if paired with a gas turbine. A 49-MW gasification plant would therefore require 166 – 185 million gallons of water per year. Fort Hood's current water rights are sufficient to accommodate this additional water usage, despite drought conditions in the area.

Like all steam cycle power plants, the boilers of a WTE plant require high-quality water (e.g., low dissolved oxygen, slightly basic pH, and low total dissolved solids) to minimize corrosion problems and blowdown requirements. Although the requirements for cooling water are typically not as stringent as boiler water, cooling water must also be treated to minimize inorganic and microbial-based corrosion, which causes equipment failure and fouling of heat exchange surfaces (GE 2011). Boiler and cooling water treatment can be accomplished with a variety of physical and chemical techniques. With proper treatment, captured storm water runoff and other forms of reclaimed water can be used as cooling water.

Water contamination is not an issue. Neither feedwater to the boiler nor cooling water comes into contact with MSW feedstock or combustion products. The only water discharge from the plant would consist of high-salinity blowdown (water released from the boiler to clear out solid particulates or salts that cause foaming), which would be sent to the wastewater treatment plant.

To prevent possible groundwater contamination from the stored MSW, prevention techniques such as those used in landfills (e.g., liners) or covered storage areas would be used.

Transportation

Feedstock will need to be trucked to the WTE plant if it is large-scale, and ash will need to be taken away. Each truck can carry 20-30 tons of MSW, so truck traffic to and from the site would increase by about 61 trucks a day to transport the approximate 1,217 tons/day of MSW plus 304 tons of ash required for a plant using 442,000 tons of MSW per year. This would increase both traffic and (scope 3) exhaust emissions. Scope 3 emissions would be reduced if the WTE plant site is closer to the waste sources than the landfill.

The plant should be located where disturbance from truck traffic, noise, and odor would be minimized. This is typically near or outside a gate, within an existing industrial area, or at another remote location with good road access. Locating the facility near a gate and providing direct access for delivery trucks without requiring entry onto the site would also address potential security concerns.

Solar PV

Solar PV systems typically pose few environmental concerns, and the construction of a PV array rarely impacts geology, seismicity, socioeconomic conditions, environmental justice concerns, or health and safety. Construction and operation may impact soils (e.g., soil infill, trenching, etc.), water resources, air quality (i.e., from trucks and construction equipment), vegetation, protected species, and cultural resources. However, mitigation measures can be taken to lessen these impacts, and some sensitive plants and animals may and often can be relocated. Munitions dangers can be a concern and areas with legacy munitions issues should be avoided or mitigated. In addition, Occupational Safety and Health Administration guidelines must be followed and careful coordination with site personnel will be necessary to minimize dangers associated with spent munitions.

Approximately 10,000 gallons/MW/yr of low mineral content water would be required for PV module washing. Construction would require approximately 50-100 gallons/MW/day for dust control, but lower quality water can be used for this application (BNL 2009).

Summary

Table 20: Summary of Potential Renewable Resources at Fort Hood

	Wind	MSW	Solar PV	Landfill Gas	Shale Gas
Resource Availability	6.5 m/s at 80 m	444,174 tons/year potentially available from surrounding area, but importing MSW is unlikely	4.7 to 6.3 kWh/m^2/day, depending on technology	None to minimal methane from onsite landfill; no nearby landfills	The geologic conditions that define a productive shale gas resource are not present
Economic Feasibility	10.3¢/kWh required for a 10% IRR	12.0¢/kWh required for a 10% IRR for a 49 MW gasification project	19.6¢/kWh – 30.9¢/kWh required for a 10% IRR, depending on technology	~11.0¢/kWh required for a 10% IRR if methane was recoverable	N/A
Major Environmental Impacts	Mission conflicts, impact to endangered species	Emissions, hazardous waste (ash), increased truck traffic	None	N/A	N/A
Development Options	Third-party developer	Third-party developer	Third-party developer for large project, ECIP funding for small or roof-mounted arrays	N/A	N/A
Development Locations	TA 60-66 or TA 40-46	Site near Clear Creek Road entrance	Various open land near substations, identified buildings	N/A	N/A
Potential Energy Generation	4,022 MWh/yr per 1.6 MW turbine. 82 MW, ~200,000 MWh/year to meet DOD 25% goal	49 MW, 385,219 MWh/year for gasification	1,502 MWh/yr per 1 MW of modules. 135 MW, ~200,000 MWh/year with ground-mounted, fixed-tilt array to meet DOD 25% goal	N/A	N/A
Land Requirements	40 – 60 acres per MW. 51 turbines to meet DOD 25% goal	5 – 10 acres total	3 – 5 acres per ground-mounted MW. 700 acres to meet DOD 25% goal	N/A	N/A
Recommendations	Pursue EDP Renewables as a development partner for off-site project	Investigate small-scale gasification projects if large-scale is not an option	Pursue opportunities for roof-top installations as economics improve	Do not pursue	Do not pursue

Recommendations and Next Steps

Given the availability of the resources on site and the economic assumptions of this assessment, there are no renewable energy projects that are clear winners. The most promising renewable energy development options for Fort Hood are wind, solar PV, and WTE, but each of these has economic, availability, or site constraint challenges.

These issues, and recommendations on how to address them, are described below for each resource.

Wind

Fort Hood has a moderate wind resource on site resulting in only a marginally economic project. If Fort Hood would like to pursue an on-site wind energy project, it should first:

- Evaluate the potential project locations identified in this assessment for mission and environmental conflicts
- Verify the on-site wind resource by siting a meteorological tower that collects wind data for a minimum of one year in an approved location
- After the wind resource is verified, project economics must be reevaluated and further consideration can be given to a wind energy project on site

Because of the moderate wind resource at Fort Hood, a project off-site with a better wind resource may be more economic, depending on transmission costs. If Fort Hood is not interested in pursuing an on-site project, it should explore PPA options with EDP Renewables, or other development partners.

Municipal Solid Waste

Fort Hood is designated as a net-zero waste installation and therefore has a strong interest in solid waste management. This includes both a reduction of the current waste stream and use of the remaining waste for energy generation. After achieving its waste reduction goals, Fort Hood will have a very small waste stream that will not be able to power a cost-effective WTE plant on its own. An economic, large-scale, on-site WTE project would require the import of MSW, which is unlikely to happen because of Fort Hood's environmental policies and the assumption that importing MSW would conflict with net-zero waste goals. Off-site large-scale projects to which Fort Hood could send its waste do not currently exist and are unlikely to be built in the near future. If a small-scale project sized to handle just Fort Hood's waste stream is desired, an investigation of small-scale gasification technologies, which are just entering the market, will be needed. The installation is primarily interested in gasification, not combustion, to reduce environmental impacts and maximize conversion efficiency.

Solar PV

While not currently economic, roof-top solar applications appear to have wide support at Fort Hood (no land use or mission conflicts), and with PV prices dropping, Fort Hood should pursue roof-top solar PV projects as appropriate opportunities arise.

Landfill Gas

It is not recommended that Fort Hood pursue a landfill gas project because of lack of available resources.

Shale Gas

Based on existing data, the geologic conditions that define a productive shale gas resource are not present at Fort Hood. Therefore, Fort Hood should not pursue on-site shale gas production, but should remain open to legitimate exploration proposals, if they should arise.

Regional Approach

Instead of trying to develop marginally economic on-site projects, Fort Hood could lead the TREX effort and develop regional projects jointly with other DOD and Federal agencies. The resources on Fort Hood are not ideal and there may be better opportunities on other Federal lands that could be developed to benefit multiple regional partners at a lower cost for each.

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Appendix A: Waste-to-Energy Technologies

Waste-to-energy (WTE) is the process of using municipal solid waste (MSW) and/or construction and demolition (C&D) waste as fuel sources for energy generation. These feedstocks qualify as renewable sources for Energy Policy Act of 1992 (EPAct) compliance purposes, but some states (including Texas) and alternative goals have different requirements.

Historically, WTE technologies have been large-scale combustion systems, commonly called incinerators. These have been used primarily to reduce the amount of waste sent to landfills, with a secondary purpose of energy generation. Newer technologies, including thermal and plasma gasification, are more energy efficient, less polluting, and varying in size to accommodate different resource scenarios.

Combustion systems incinerate waste to produce steam in a boiler. The steam can be used directly as thermal energy or used to generate electricity by turning a turbine connected to a generator. This method of producing electricity is about 20 to 30% efficient. In these systems, combustion products tend to form deposits on the heat transfer surfaces thereby causing corrosion and erosion which increase maintenance requirements and decrease the lifetime of these surfaces. Typical combustion system designs include moving grate and fixed grate stoker boilers (mass burn) and stationary and circulating fluidized beds (which use a gas pushed through hot sand or a similar medium as the bed on which the feedstock is heated). Small-scale combustion plants typically employ stationary mass burn technologies and are mostly used for direct heating applications or simply waste incineration without energy recovery. Large-scale plants tend to be fluidized beds.

Gasification uses steam, heat, pressure, and sometimes oxygen to break down organic materials to produce syngas, which is primarily hydrogen and carbon monoxide. Syngas is cleaned to remove impurities, then is used to generate electricity in a gas turbine or fuel cell, or is used to produce fuels and/or commercially valuable chemicals. The inorganic materials are discharged as inert solids that can often be used for another purpose. Gasification is more efficient than combustion, typically in the 30-40% range for electricity production. However, required preprocessing of MSW feedstock is more extensive than for combustion technologies because although they both operate better with homogenous feedstock, gasification is more sensitive to variations. There are many types of gasification designs that use different amounts of oxygen and steam at different stages and temperatures, producing different amounts of waste heat, syngas, and solids. Some standard designs include updraft and downdraft fixed beds, bubbling and circulating fluidized beds, and entrained flow. Fixed bed systems are smaller scale while fluidized bed and entrained flow systems are typically large-scale.

One type of gasification uses plasma to gasify the waste at extremely high temperatures. Plasma technologies are much more expensive than combustion or gasification, and have a high parasitic load, but break down waste much more thoroughly than the other technologies. As a result, hazardous waste can be consumed in these plants and there are far fewer emissions. Plasma systems are newer to the U.S. market and typically small-scale because of their expense at this time, but large-scale systems are already in operation in Japan.

WTE technologies can also be differentiated by size: large-scale (10 MW and larger) and small-scale (typically less than 5 MW). Large-scale technologies require large amounts of waste from the region, typically at least 100,000 tons/year (about 275 tons/day). Small-scale plants can be sized to just consume the waste generated at a location, regardless of the amount. Very small plants will consume energy rather than produce it.

Table A-1 summarizes the technologies and some operational details.

Table A-1: Characteristics of Standard WTE Technologies

Technology	Scale	Economics	Electric Efficiency	Emissions	Applications
Combustion	Small	Cost-competitive	Unknown	Can be an issue	Direct thermal
Combustion	Large	Can be cost-competitive depending on tipping fees	20-30%	Can be an issue; extensive control equipment may be required	Baseload electricity, central heating/cooling plants
Gasification	Small	Unproven, but likely to be high cost per output	25-40%	Low total emissions	Waste treatment for smaller waste streams, electricity, central gas boiler
Gasification	Large	Unproven, but may be cost-competitive depending on tipping fees	30-40%	Relatively low; some control equipment required	Baseload electricity, synthetic natural gas, industrial chemicals
Plasma gasification	Small	Expensive unless used with costly waste streams, or to produce valuable products	10-25%	Zero for plasma process; use of syngas generates few emissions	Waste elimination, hazardous waste, industrial chemicals, electricity