# Prevention of Significant Deterioration Greenhouse Gas Permit Application Bethel Energy Center, Anderson County, Texas

Prepared for

## APEX Bethel Energy Center, LLC

Submitted to

## U.S. Environmental Protection Agency Region 6

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CH2MHILL®

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# Executive Summary

APEX Bethel Energy Center, LLC (APEX) plans to construct the Bethel Energy Center, a 317 MW Compressed Air Energy Storage (CAES) facility located near Tennessee Colony, Anderson County, Texas (Project). CAES is a commercially available, economically attractive form of bulk energy storage for the electricity grid.

The proposed Bethel Energy Center will produce electricity by compressing air during low demand periods for subsequent use in generating electricity during high demand periods. This facility has the unique capability of providing bulk energy storage which enhances the performance of intermittent renewable (wind and solar facilities) and conventional fossil fuel energy generation. Worldwide, two CAES plants – the McIntosh plant in Alabama and the Huntorf facility in Germany – have operated successfully for over 20 years.

The CAES technology involves two major processes: (a) air compression and storage and (b) air release for electricity generation. During the air compression and storage process, electric motor driven compressors are used to inject air into an underground cavern (or other storage media) for storage under high pressure. The storage cavern for the Bethel Energy Center will be created by leaching a void space in an underground salt formation (the Bethel Dome) located directly beneath the plant site. The Bethel Energy Center storage cavern is expected to operate over a wellhead pressure range of approximately 1,900 to 2,830 psia (static pressure range). Electricity is generated by releasing the high-pressure air, heating the air with natural gas, and expanding it through sequential turbines ("expanders"), which in turn drive an electrical generator. When full, the inventory of stored air will support approximately 100 hours of generation at full rated generation output without recharge.

The compression and expansion equipment for the McIntosh Plant was supplied by Dresser-Rand. Notwithstanding the absence of a follow-on CAES project (subsequent to installation of the McIntosh facility), Dresser-Rand has maintained its commercial offering of CAES technology, and today Dresser-Rand is the only equipment manufacturer offering an integrated CAES design, along with performance guarantees across the compression and generation functions.

The Bethel Energy Center will include a number of design enhancements in comparison to the McIntosh plant. These enhancements will serve to increase the efficiency of the plant, both with regard to fuel and air use, to enhance operating flexibility, and to reduce water consumption associated with compressor cooling.

In accordance with the terms of federal Prevention of Significant Deterioration (PSD) regulations, APEX is applying to U.S. Environmental Protection Agency (EPA) Region 6 for a PSD permit to construct the Bethel Energy Center. The application is limited to requesting a permit for the emissions of greenhouse gases (GHGs) from the Bethel Energy Center and contains a description of the Project, a review of applicable federal regulations, a listing of the emissions, and a best available control technology analysis. PSD permitting emission thresholds are not exceeded for any pollutant other than GHGs. Consequently, APEX is applying for a Texas Commission on Environmental Quality (TCEQ) Standard Permit for Electric Generating Units (EGU) to authorize emissions of pollutants other than GHGs.

The Bethel Energy Center will have potential GHG emissions (comprised of carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), methane ($CH_4$), and sulfur hexafluoride ($SF_6$) of 459,125 tons per year (tpy) $CO_2$-equivalent ($CO_2$e). Because the emissions of $CO_2$e exceed 100,000 tpy, this plant will be a major new source subject to the GHG PSD rules.

In accordance with the requirements of the federal PSD program and EPA's PSD permitting guidance for GHGs, a best available control technology (BACT) analysis was performed. The BACT analysis concludes that the APEX Project design represents BACT for GHGs.

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# Acronyms and Abbreviations

| | |
|---|---|
| APEX | APEX Bethel Energy Center, LLC. |
| BACT | best available control technology |
| CAA | Clean Air Act |
| CAES | Compressed Air Energy Storage |
| CatOx | catalytic oxidation |
| CEM | continuous emissions monitor |
| CFR | Code of Federal Regulations |
| $CH_4$ | Methane |
| CCN | Certificate of Convenience and Necessity |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| $CO_2e$ | carbon dioxide equivalent |
| DOE | U.S. Department of Energy |
| ERCOT | Electric Reliability Council of Texas |
| °F | degrees Fahrenheit |
| EPA | U.S. Environmental Protection Agency |
| FIP | Federal Implementation Plan |
| FR | *Federal Register* |
| GHG | greenhouse gas |
| GWP | global warming potential |
| HFC | Hydrofluorocarbon |
| HHV | higher heating value |
| HP | high-pressure |
| IPCC | Intergovernmental Panel on Climate Change |
| kW | Kilowatt |
| kWh | kilowatt-hour |
| LAER | lowest achievable emission rate |
| lb | Pound |
| lb/hr | pound per hour |
| LDAR | leak detection and repair |
| LHV | lower heating value |
| LP | low-pressure |
| MACT | maximum achievable control technology |

| | |
|---|---|
| MRR | Final Mandatory Reporting of Greenhouse Gases Rule, or Mandatory Reporting Rule |
| MMBtu | million British thermal units per hour |
| MW | Megawatt |
| NAAQS | National Ambient Air Quality Standards |
| NSR | New Source Review |
| $NO_X$ | nitrogen oxide |
| $N_2O$ | nitrous oxide |
| $O_2$ | Oxygen |
| PFC | Perfluorocarbon |
| $PM_{10}$ | particulate matter less than 10 microns in diameter |
| $PM_{2.5}$ | particulate matter less than 2.5 microns in diameter |
| ppm | parts per million |
| PTE | potential to emit |
| PSD | Prevention of Significant Deterioration |
| PUC | Public Utility Commission |
| RACT | Reasonably Available Control Technology |
| SCGT | Simple Cycle Gas Turbine |
| SCR | selective catalytic reduction |
| $SF_6$ | sulfur hexafluoride |
| SIP | State Implementation Plan |
| $SO_2$ | sulfur dioxide |
| TCEQ | Texas Commission on Environmental Quality |
| TDU | Transmission and Distribution Utility |
| tpy | tons per year |
| VOC | volatile organic compound |

SECTION 1.0
# Introduction

APEX Bethel Energy Center, LLC (APEX) plans to construct the Bethel Energy Center, a 317 MW Compressed Air Energy Storage (CAES) facility located near Tennessee Colony, Anderson County, Texas. CAES is a commercially available, economically attractive form of bulk energy storage for the electricity grid.

Recent years have seen a rapid increase in the amount of renewable electric generating resources – especially wind energy. For example, installed wind generation in the Electric Reliability Council of Texas (ERCOT) region has more than doubled over the past five years, to approximately 9,600 MW (nameplate). [Source: ERCOT Capacity/Demand/Reserves Reports, 2007 and May 2012]

This rapid growth in renewable forms of power generation is the result of a number of public policy initiatives encouraging the construction of renewable generation, at both the state and federal level. Addition of a significant amount of renewable generation has created a number of challenges for the grid operator (ERCOT) with regard to managing the overall stability and reliability of the bulk power system, for reasons explained below.

The grid operator must take actions to balance the supply of power against demand on a near instantaneous basis. If demand exceeds supply, the system frequency will begin to decline from the objective of 60 Hz; conversely, if supply is greater than demand, frequency will begin to increase. Because demand changes continually, grid operation requires a constant series of adjustments in the operation of the on-line generation fleet (as well as use, on a more limited basis, of customer "demand side" response).

Renewable generating resources such as wind and solar can complicate grid operation in a number of ways. First, by definition these resources are intermittent – neither the magnitude of wind velocity nor solar intensity can be controlled. Secondly, because the marginal production cost of these resources is essentially zero, the grid operator will make every effort to accommodate output from these resources, even when demand on the system is very low. In fact, because many renewable resources benefit from a federal production tax credit (approximately $22/MWh), these resources can remain profitable at power market prices as low as negative $22/MWh.

As the amount intermittent generating resources has increased, so has the grid operator's need flexible "stand-by" resources capable of responding quickly to deviations in system frequency. Additionally, wind generation, which in West Texas typically peaks during nighttime hours, can act to suppress off-peak prices. For example, in 2011 the ERCOT west zone experienced 349 hours of negative prices, with 993 hours below $10/MWh. [Source: ERCOT Market Information System.]

These circumstances support the economic attractiveness of grid-level energy storage in the ERCOT market. Such resources could provide valuable quick response capability, as well as serving to ameliorate off-peak grid management issues, by time shifting off-peak energy to periods of higher demand.

Only two technologies are commercially available and capable of proving sufficient storage capacity to be of value at the bulk power level – CAES and pumped hydroelectric ("hydro") generation. Both technologies are dependent on suitable geographic/geologic features. Pumped hydro requires a river with substantial elevation change; CAES requires suitable underground storage media. While no practical sites for pumped hydro exist in Texas, the state has numerous underground salt deposits, in the form of salt domes in the eastern and gulf coast regions, and bedded salt in the western regions of the state. Additionally, the natural gas industry has decades of experience with the storage of high-pressure natural gas in underground caverns formed by leaching (dissolving with water) a void space in the salt. Storage of air represents a relatively straightforward extension of underground natural gas storage experience.

CAES technology involves two major processes: (a) air compression and storage and (b) air release for electricity generation. During the air compression and storage process, electric motor driven compressors are used to inject air into an underground cavern (or other storage media) for storage under high pressure. Electricity is generated by releasing the high-pressure air, heating the air with natural gas, and expanding it through sequential turbines ("expanders"), which in turn drive an electrical generator. Worldwide, two CAES plants – the McIntosh plant in Alabama and the Huntorf facility in Germany – have operated successfully for over 20 years.

APEX conducted an evaluation of more than 20 potential sites in west and southeast Texas to identify potential cavern creation opportunities before selecting the Bethel Energy Center site. The Bethel Energy Center site was chosen for development of a CAES facility due to the presence of suitable geologic conditions, existing gas and electric transmission lines crossing the property, existing infrastructure to support cavern creation, and availability of groundwater as a water source. Appendix A includes a map showing the location of the Bethel Energy Center.

The storage cavern for the Bethel Energy Center will be created by drilling a "cavern well" approximately 6000 feet into the underground salt deposit. Fresh water withdrawn from local groundwater wells will be pumped down the well to dissolve salt, creating the storage cavern. Salt brine withdrawn from the cavern during this "leaching" process will be injected into existing permitted brine disposal wells on nearby property. This leaching process, expected to require 700 to 800 days, will be carefully controlled to produce a cavern of the desired capacity and shape.

Dresser-Rand, the equipment supplier for the McIntosh CAES installation, has continued to offer CAES technology to the market. Indeed, today Dresser-Rand is the only equipment manufacturer providing both the compression and expansion equipment for CAES, along with performance guarantees. Apex plans to use Dresser-Rand supplied equipment for the Bethel Energy Center. However, the Bethel Energy Center will incorporate several design improvements in comparison to the McIntosh plant. One major change is complete separation of the compression and expansion/generation functions. At McIntosh, a single electrical machine functions as a motor when compressing, and as a generator when expanding. This is accomplished by connecting the motor/generator via clutches to the compression train and the expansion train. While this design results in capital cost savings (avoiding the cost of a second electrical machine), it constrains operating flexibility for the expansion and compression activities. Apex will install a dedicated motor for compression, and a dedicated generator for expansion/generation, allowing simultaneous operation of both functions. This added operating flexibility increases the value of the CAES facility to the grid.

Numerous other changes in comparison to McIntosh have the effect of improving the fuel heat rate, reducing specific air consumption (air use per MWh generated), increasing the useful operating range (valuable when providing quick response services to the grid), reducing $NO_X$ emissions, and reducing water consumption associated with gas cooling during compression. These design changes will be explained more completely in following sections.

The APEX Bethel Energy Center Project will consist of the following emission sources:

- Two expansion/generation trains, with each train consisting of three expansion turbines, operated in parallel, capable of generating 158.34 MW of electricity
- Two sets of cooling towers to reject heat produced during the compression process
- One natural gas fired emergency generator engine
- An aqueous ammonia storage and feed system for a Selective Catalytic Reduction (SCR) emission control system for nitrogen oxides ($NO_X$)
- Equipment fugitive emissions from pumps, valves, flanges, etc. (principally associated with the natural gas fuel supply system)

In accordance with the federal Prevention of Significant Deterioration (PSD) regulations, APEX is applying to U.S. Environmental Protection Agency (EPA) Region 6 for a permit to construct the Bethel Energy Center. The application is limited to requesting a permit for the emissions of greenhouse gases (GHGs) from the Bethel Energy Center and contains a description of the project, a review of applicable federal regulations, a listing of the emissions, and a best available control technology analysis. PSD permitting emission thresholds are not exceeded for any other pollutant. Consequently, APEX is applying for a Texas Commission on Environmental Quality (TCEQ) Standard Permit for Electric Generating Units (EGU) to authorize emissions of pollutants other than GHGs.

Section 1.1 provides Project contacts and Section 1.2 provides an overview of the documentation being submitted with the application for a permit to construct the Bethel Energy Center.

## 1.1 Project Contacts

The following individuals may be contacted for additional information on this Project:

| | |
|---|---|
| Applicant | Stephen Naeve<br>Chief Operating Officer<br>APEX Bethel Energy Center, LLC<br>3200 Southwest Freeway, Suite 2210<br>Houston, TX 77027<br>Phone: (713) 963-8104<br>email: stephen.naeve@apexcaes.com |
| Permitting Consultant | Ashley Campsie<br>Senior Project Manager<br>CH2M HILL, Inc.<br>9193 South Jamaica Street<br>Englewood, CO 80112<br>Phone: (720) 286-1236<br>email: ashley.campsie@ch2m.com |

## 1.2 Document Overview

The following is an overview of the information included in this permit application.

- **Section 1.0 – Introduction.** This section provides an overview of the Project and describes the application organization.
- **Section 2.0 – Project Description.** This section includes a general description of the proposed Project including equipment and operations of the Project. Information regarding non-emitting processes and equipment is provided for a general understanding of plant operations.
- **Section 3.0 – Greenhouse Gas Emissions Summary.** This section provides a summary of emissions-related information.
- **Section 4.0 – Greenhouse Gas Regulatory Review.** This section contains a detailed regulatory review of federal GHG air regulations that may affect the permitting, construction, or operation of the proposed Project.
- **Section 5.0 – Best Available Control Technology (BACT) Analysis.** This section includes a BACT analysis for GHG pollutants. This analysis follows the EPA-prescribed five-step top-down approach. Requested permit limits are also included in this section.
- **Appendix A – Location Map, Plot Plan, and Process Flow Diagram.** This appendix includes a location map, plot plan, and process flow diagram.
- **Appendix B – Greenhouse Gas Supporting Documentation.** This appendix contains the calculations used to determine the GHG emissions for this permit application.

- **Appendix C –Permit Application Forms –** This appendix contains permit application forms. Since EPA Region 6 has not developed a specific form for GHG permits, the Texas Commission on Environmental Quality (TCEQ) Standard Permit Application form (Form PI-1S) format is provided. In addition, TCEQ Tables 1F and 2F are provided to document the emission increases associated with the Project relative to the PSD permitting thresholds.

SECTION 2.0

# Project Description

APEX proposes to construct and operate the Bethel Energy Center near Tennessee Colony, Anderson County, Texas. The proposed Bethel Energy Center will consist of two Dresser-Rand expansion turbine/generation (ETG) trains (TURBTRNA and TURBTRNB), each rated at 158.34 MW output at full load. The total generating capacity of the plant will thus be approximately 317 MW. Two compression trains will be installed, each driven by an electrical motor of 150 MW (nominal) power rating. Two sets of cooling towers will be installed to reject heat produced during compression. The proposed Bethel Energy Center will also have an emergency generator engine fired with natural gas, and an aqueous ammonia storage and feed system for the Selective Catalytic Reduction (SCR) emission control system.

## 2.1 Facility Location and Plot Plan

Maps showing the facility location and the planned facility layout are presented in Appendix A. The plot plan identifies the arrangement of key Project components and equipment.

CAES facilities require an underground storage cavern for storage of compressed air. In Texas, salt domes provide the unique geologic conditions necessary for cavern creation but are only present in selected areas within the state. APEX conducted an evaluation of more than twenty potential sites in west and southeast Texas before selecting the Bethel Energy Center site. The proposed Bethel Energy Center site was selected for development of this facility due to the presence of suitable geologic conditions, existing gas and electric transmission lines crossing the property, availability of existing infrastructure to support cavern creation, and groundwater as a water source. Portions of the property were previously developed and contain existing pipeline facilities.

## 2.2 Bethel Energy Center CAES Operation

The Bethel Energy Center will employ two Dresser-Rand CAES compression trains, each consisting of a multi-stage compressor section driven by a dedicated 150 MW (nominal rating) electric motor. Each compression train will be capable of producing up to 1.4 million pounds per hour of air at a compressor outlet pressure of up to 2,830 psia. The expansion/generation component of the plant will consist of two expansion turbine/generator trains, each rated at 158.34 MW. Thus at maximum compression load, the facility will consume up to 300 MW of energy, while at maximum generator output the facility will produce approximately 317 MW.

The cavern well casing shoe for the Bethel Energy Center will be set at a depth of approximately 3750 feet. The operating pressure range of gas storage in salt is a function of this casing shoe depth. For natural gas, the Texas Railroad Commission rules stipulate that maximum storage pressure at the casing shoe (in pounds per square inch (psia)), cannot exceed a factor of 0.85 times the casing shoe depth, expressed in feet. Thus a cavern with a casing shoe depth of 3750 feet will have a maximum pressure of 3188 psia. Minimum cavern pressure is typically dictated by a number of factors, including the magnitude and frequency of cavern injections and withdrawals. Based on cavern modeling efforts, APEX expects the Bethel Energy Center cavern to operate over a wellhead pressure range of approximately 1,900 to 2,830 psia (static pressure range). If full, the cavern will support approximately 100 hours of generation at full rated output without recharge.

The expansion/generation components of a CAES facility share certain fundamental characteristics with conventional utility scale gas turbines – both technologies use a compressible gas as the working fluid, operating on the same thermodynamic cycle (the Brayton cycle). However, equipment design and configuration are, in certain respects, profoundly different.

A simple cycle gas turbine (SCGT) has a compressor section, followed by an expander section, connected on a common shaft with an electrical generator. Inlet air is compressed (at a compression ratio of approximately 16:1

in a modern utility scale machine), fired with natural gas, and the resulting hot, high-pressure gas is expanded through a turbine. The work done in the expansion turbine drives both the compression section and the generator.

While suitable for certain services, the SCGT has significant operational drawbacks – most notably, a relatively limited load range. Minimum load for a SCGT is typically 50 to 60 percent of maximum output, and heat rate deteriorates as the machine output is reduced from full load. The SCGT operating range is heavily influenced by operational limits of the compressor section. A compressor simply cannot be designed to operate efficiently over a broad range of flow rate/pressure ratio.

Because CAES expanders are supplied with high-pressure air from the storage cavern, CAES operation is unaffected by turndown limitations of a compressor. Thus the expansion trains at the Bethel Energy Center will be capable of operating sustainably at an extremely low output (less than 10% of maximum rated output), with the ability to ramp to full load in less than five minutes.

This exceptional response rate and broad operating range make CAES ideal for providing grid reliability services such as frequency regulation or standby capacity (commonly called “spinning reserves”). Within ERCOT the wholesale market compensates generators for provision of such grid reliability services (termed Ancillary Services).

CAES technology differs from conventional gas turbine technology in other important ways. For example, the Bethel Energy Center uses three expanders, operating on a single shaft, connected to the generator. High-pressure air from the cavern passes sequentially through the three expanders, performing work (accompanied by a reduction in pressure) as the air flows through each stage of expansion. The lowest stage of expansion operates at an inlet pressure comparable to industrial scale gas turbines, and thus its design resembles a conventional gas turbine. However, the two higher-pressure expanders operate at pressures far in excess of a typical gas turbine. These machines are based on Dresser-Rand steam turbine design experience. (Utility scale steam turbines commonly operate at pressures in excess of 2000 psia).

A process flow diagram for the Bethel Energy Center plant is provided in Appendix A. It depicts the compressors, operating at design basis compression, under summer ambient conditions, and further assuming a “near” full cavern. Compression occurs in four stages. Because compression of air results in an increase in temperature, it is necessary to cool the air between the stages. Heated water from this process will be cooled in a conventional mechanical draft cooling tower. Make-up water to the cooling tower will be sourced from onsite wells. Cooling tower blow down will be discharged via pipeline to the Trinity River. Maximum daily water consumption is expected to be approximately 1 million gallons (assuming summer operation, twelve hours of compression at high compressor flow). Annual water requirements are expected to be approximately 400 ac ft.

The process flow diagram in Appendix A also depicts the expansion/generation process. At maximum generator output, approximately 400 lbm/second of air from the cavern header passes through a recuperator, where the air is preheated to a temperature of 600°F before entering the topping turbine, at a turbine inlet pressure of approximately 2,300 psia. Air is expanded in the topping turbine, resulting in a temperature and pressure drop. The air next flows to one of two high-pressure (HP) combustors. Natural gas is burned with the air in the HP combustors, and the resultant heated gases enter the HP expander at approximately 1,000 °F and 800 psia. The gases exit the HP expander, flowing to the low-pressure (LP) combustors, where additional natural gas is burned to increase the gas temperature for further expansion in the LP expander. Gases exiting the LP expander flow through the recuperator, preheating the air from the cavern, and exhaust to the stack.

The addition of a topping turbine is a design feature unique to the Bethel Energy Center. This addition is made possible by the fact that the cavern pressure at Bethel (which has been optimized on the basis of numerous site specific geological and economic parameters, including ERCOT power market considerations) is much higher than at McIntosh (or at other sites which have been studied for CAES installation).

A natural gas fired reciprocating engine will power an emergency electric generator rated at 740 ekW, necessary to support starting the plant when power from the grid is unavailable (“black start”).

### 2.2.1 Facility Operation Cycle

Economic modeling of the Bethel Energy Center predicts that the system will operate in generation service at a relatively low load (on the order of 10 to 20 percent of maximum output) much of the time, ready to respond to ERCOT instructions to quickly ramp up in order to provide Ancillary Services. At other hours of the year, the plant is expected to operate at or near full load. APEX is electing to limit the Project fuel usage in order to stay below PSD significant levels for criteria pollutants. The emissions presented in this permit application are based on this fuel use limit.

### 2.2.2 Support of Wind Power Integration

The proposed Bethel Energy Center will produce electricity by compressing air during low demand periods for subsequent use in generating electricity during high demand periods. This facility has the unique capability of providing bulk storage of energy generated by wind and solar energy facilities during periods of low electrical demand. Installed wind capacity within ERCOT has increased from 863 MW in 2002 to 9,609 MW at year end 2011, representing an eleven-fold increase. [Source: ERCOT Capacity/Demand/Reserves Report, 2002 and December 2011.]

In numerous reports, the United States Department of Energy (DOE) has addressed the role storage can play in accommodating intermittent renewable generation resources:

- “Energy storage can further enhance the potential of renewable energy by providing load shifting, peak shaving, dispatchability, and a means to bring stranded renewable energy into the grid.” (DOE, 2012)
- “In grids with a significant share of wind generation, intermittency and variability in wind generation output due to sudden shifts in wind patterns can lead to significant imbalances between generation and load that in turn result in shifts in grid frequency. Such imbalances are usually handled by spinning reserve at the transmission level, but energy storage can provide prompt response to such imbalances without the emissions related to most conventional solutions.” (DOE, 2008a)
- *“*Energy storage technologies are not an alternative to any particular resource decision; rather, they are a valuable adjunct to all resources, and they will allow increased capacity to be derived from any given quantity of physical resources.” (DOE, 2008b)

The Bethel Energy Center enhances the integration of wind (and other intermittent generating resources, such as solar power) within the ERCOT market.

## 2.3 Emission Sources

### 2.3.1 Expansion Turbine Generators

The Bethel Energy Center will consist of two 158.34-MW expansion turbine trains. Electricity generation will involve passing compressed air through the topping, high pressure and low pressure expansion turbines and heating the air with natural gas in advance of the high pressure and low pressure expansion turbine stages. In addition, the air is preheated before entering the first stage of expansion in a recuperator, capturing exhaust heat from the expanders.

### 2.3.2 Wet Cooling Towers

Two sets of wet cooling towers will be installed to cool the air entering the electric compressor. Since this source does not emit GHG emissions, it is not included in the GHG BACT analysis.

### 2.3.3 Fugitive Emissions

Process fugitive emissions consist of natural gas emissions from pressurized equipment due to leaks and various other irregular or unintended releases of gases, and sulfur hexafluoride ($SF_6$) leaks from circuit breakers. APEX is proposing a comprehensive equipment maintenance program that will include periodic inspections for leaks and subsequent repair.

### 2.3.4 Emergency Generator Engine

One natural gas fired emergency generator engine will be used to provide emergency power for the facility. This engine will fire natural gas, and will typically operate only during testing that is anticipated to occur approximately once per month for 30 minutes per testing event. For permitting purposes, the total operating hours for the emergency generator are assumed to be 50 hours per year or less. A 740 ekW Caterpillar G3516 SITA model engine is proposed for this facility.

### 2.3.5 Aqueous Ammonia Storage Tank

An aqueous ammonia storage tank will be installed to provide ammonia for the SCR emission control system employed to reduce $NO_X$ emissions from the turbine trains. This storage tank will not emit GHGs and is therefore not included in the emission inventory or BACT analysis.

## 2.4 Non-Emitting Facility Components

### 2.4.1 Ancillary Facilities

Other facilities used to support power generation at the Bethel Energy Center will include the following:

- Water treatment system to remove solids and hardness from plant makeup water
- Wastewater treatment system to allow recycle of cooling tower blow-down and other plant wastewater
- Plant and instrument air compressors (electric-driven) and auxiliary equipment
- Plant sumps and sump pumps
- An electrically-driven fire pump
- Miscellaneous fire protection equipment
- A pipeline for discharge of cooling water blowdown to the Trinity River (or a municipal publically owned treatment facility)
- Septic system for sanitary waste
- Process/potable water wells
- Administration and warehouse/maintenance buildings
- Air storage cavern

Electrical transmission will also be required for the facility development. Within ERCOT, the transmission lines are independently sited and operated by a Transmission and Distribution Utility (TDU), not the generator. The TDU, not APEX, will evaluate the alternative routes and present its case to the Texas Public Utility Commission (PUC) in accordance with the PUC's rules and procedures for granting of a Certificate of Convenience and Necessity (CCN) for new transmission line construction or upgrading. Under this law and by PUC practice, comprehensive evaluation of environmental impacts of proposed lines is required as a component of the CCN approval process. Once a route for any new construction (as well as plans for any necessary network upgrades) is approved, the TDU will design, build, own, and operate the interconnection facilities. Texas law and PUC rules entitle generators to interconnection with costs (other than the step-up transformers and related protection at the plant site) being borne by the broad market.

## 2.5 Emission Controls

The Bethel Energy Center will include the following air emission controls:

- Low $NO_X$ burners with water injection on the expander combustors and a SCR system to reduce $NO_X$ emissions from the expansion turbine train
- An oxidation catalyst to reduce carbon monoxide (CO) and volatile organic compound (VOC) emissions from the expander combustors
- Good combustion design and operation to reduce emissions of particulate matter of 10 microns in diameter ($PM_{10}$) and 2.5 microns in diameter ($PM_{2.5}$) from the expander combustors
- Use of pipeline-quality natural gas to minimize sulfur dioxide ($SO_2$) emissions from the expander turbine trains
- High-efficiency drift eliminators on the cooling towers to reduce $PM_{10}$ and $PM_{2.5}$ emissions in the cooling tower drift
- NSCR system controlling $NO_X$, CO and VOC emissions from the emergency generator engine

## 2.6 Emissions Monitoring

APEX is proposing to monitor the quantity of fuel combusted by the turbines in order to calculate carbon dioxide ($CO_2$) emissions. The facility will also analyze the natural gas fuel quality as required by the acid rain rules to determine the higher heat value of the fuel (or Carbon Based Fc-Factor as presented in 40 CFR Part 75). This approach will be consistent with acid gas rules in 40 CFR Part 75, GHG Mandatory Reporting Rules in 40 CFR Part 98, Subpart D, and the proposed NSPS Subpart TTTT rule.

## 2.7 Operating Schedule

The annual operating schedule of the Bethel Energy Center will be dependent on the demand for electric power within the ERCOT system. Thus, the exact operating schedule cannot be precisely predicted at this time.

The permit limits requested in this application, and the resulting assumptions used in the GHG emission calculations and BACT analysis, are as follows:

- Up to 7,807,409 MMBtu per year of operation (including normal operation, startups, and shutdowns) for both turbine trains combined at various loads (100 percent load or at any lesser load rate), based on high heating value of the natural gas fuel
- Up to 365 startups and 365 shutdowns for each turbine train per year
- Up to 50 hours per year operation of the emergency generator engine

The expansion turbine fuel usage is based on continuous operation. In other words, the facility could operate up to 8,760 hours per year (counting startup and shutdown episodes) and could operate 24 hours per day, 7 days per week, and 365 days per year.

## 2.8 Permitting and Construction Schedule

The planned permitting and construction timeline is shown in Table 2-1.

TABLE 2-1
**Permitting and Construction Schedule**

| Event | Date |
| --- | --- |
| Air Permit Application Filed with EPA | June 21, 2012 |
| Air Permit Application Filed with TCEQ | June 28, 2012 |
| Air Permits Issued by EPA and TCEQ | December 15, 2012 |
| Start of Construction | 1st Quarter 2013 |
| Commercial Operation | 1st Quarter 2016 |

SECTION 3.0

# GHG Emissions Summary

GHG emission estimates were prepared for all emissions sources from the Bethel Energy Center, including the turbines and auxiliary equipment. Detailed GHG emission calculations are provided in Appendix B.

## 3.1 Expansion Turbines

The APEX Project consists of two nominal 158.34-MW expansion turbine generators. Each expansion turbine train has a separate stack. GHG emissions for the expansion turbine trains were calculated for normal operating mode as well as startup and shutdown events, using emission factors obtained from the federal Mandatory GHG Reporting Rule, 40 CFR Part 98. The design maximum natural gas fuel usage rates utilized in the calculations were increased by three percent to account for equipment degradation between overhauls. The annual carbon dioxide equivalent ($CO_2e$) emissions from the turbine trains were estimated based on a maximum fuel usage of 7,807,409 MMBtu of natural gas usage for both turbine trains combined (including startup and shutdowns).

## 3.2 Auxiliary Equipment

In addition to the two expansion turbine trains planned for the Bethel Energy Center, there are fugitive emissions from equipment leaks and an emergency generator that will emit GHGs. Facility maintenance may also emit GHGs during equipment purging prior to inspection and repairs. Estimated GHG emissions from the auxiliary equipment and maintenance activities are:

- Fugitives with estimated emissions of 248 $CO_2e$ tons/year
- One (1) Natural gas-fired emergency generator (nominal 1,053 -BHP engine with estimated emissions of 23 $CO_2e$ tons/year)
- Facility maintenance activities with estimated emissions of 85 $CO_2e$ tons/year

## 3.3 GHG Emission Summary

The GHG emission sources for the Project are shown in Table 3-1, along with estimated annual $CO_2e$ emissions.

TABLE 3-1
**GHG Emission Source Summary**

| Emission Point Number | Emission Point | Estimated Annual $CO_2e$ Emissions (tons per year) |
|---|---|---|
| TURBASTK, TURBBSTK | Two (2) Nominal 158.34-MW Expansion Turbines (including normal emissions and startup/shutdown emissions) | 458,769 |
| FUG1 | Fugitives | 248 |
| GENENG1 | One (1) Natural Gas-fired Emergency Generator | 23 |
| MAINT1 | Facility Maintenance Activities | 85 |
| TOTAL | | 459,125 |

SECTION 4.0

# Regulatory Review

This section provides a regulatory review of the applicability of federal air quality permitting requirements for GHGs and GHG air pollution control regulations for the Bethel Energy Center Project. The purpose of this section is to provide appropriate explanation and rationale regarding the applicability of these regulations to the Bethel Energy Center. The review is limited to federal regulations for GHG because no State of Texas regulations for GHG apply to the permitting of Bethel Energy Center. TCEQ has not adopted regulations under the Tailoring Rule. Therefore, TCEQ is the permitting authority for the Bethel Energy Center non-GHG pollutants (other regulated New Source Review [NSR] pollutants), while EPA Region 6 is the permitting authority for the Bethel Energy Center GHG pollutants.

## 4.1 Federal Regulations

The proposed Project was evaluated to determine compliance with applicable federal GHG air quality regulations. Potentially applicable federal GHG regulations include the following:

- Final Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule (Tailoring Rule) – 40 CFR 51.166, 52.21, as published in the *Federal Register* (FR) June 3, 2010 (75 FR 31514)
- Federal Implementation Plan (FIP) for State of Texas GHG – 40 CFR 52.37, as published in the *Federal Register*: 75 FR 82246 (December 30, 2010) ) (interim rule); 76 Fed. Reg. 25178 (May 3, 2011) (final rule).
- New Source Review (NSR) – 40 CFR 51 and 52

On April 2, 2007, the U.S. Supreme Court found that GHGs are air pollutants under Clean Air Act (CAA) Section 302(g) (*Massachusetts* v. *EPA,* 549 U.S. 497 [2007]). GHG includes the six gases of $CO_2$, nitrous oxide ($N_2O$), methane ($CH_4$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and $SF_6$. Of these, the first three and $SF_6$ will be emitted from the Bethel Energy Center. These gases have different potential to affect global warming, termed the global warming potential (GWP). The GWP of the four emitted gases are: $CO_2$ (1), $N_2O$ (310), $CH_4$ (21), and $SF_6$ (23,900).

Based on the series of legal and regulatory actions that culminated in the Tailoring Rule, regulation of major increases of GHG emissions through the Prevention of Significant Deterioration (PSD) permit program is required. EPA recognized that application of the major source threshold levels for the criteria pollutants for PSD pollutants of 100 or 250 tons per year (tpy) to GHG emissions would make virtually every new project a major source. Accordingly, in June 2010, EPA adopted the Tailoring Rule to establish a major source threshold for GHG of 100,000 tons of GHG per year.

The State of Texas has an approved State Implementation Plan (SIP) based program for the criteria pollutants for the PSD permitting of new major sources. However, Texas has decided not to include GHG in the state PSD permitting program. Accordingly, the GHG PSD program is being implemented by the EPA for major sources of GHG within the State of Texas through the federally approved FIP.

### 4.1.1 Greenhouse Gas Tailoring Rule

On June 3, 2010, EPA issued the final Tailoring Rule (75 FR 31514), which allowed the phasing in of the PSD permitting process for new major sources of GHGs such as the Bethel Energy Center. Step 2 of the Tailoring Rule requires that beginning July 1, 2011, all new sources with the potential to emit (PTE) greater than 100,000 tpy of $CO_2e$ (including the statutory threshold of 100 or 250 tons on a mass basis) comply with PSD and Title V requirements. All references to "tons" are provided in terms of short tons (2,000 pounds/ton) instead of metric tonnes, in accordance with EPA GHG PSD permitting guidance.

As shown in Table 4-1, under the Tailoring Rule, the Bethel Energy Center will be a major source subject for PSD permitting because the total emissions of $CO_2$e exceed 100,000 tpy. The APEX Project will result in $CO_2$e emissions of 459,125 tpy. Therefore, the Project is classified as a major source for PSD applicability determination.

TABLE 4-1
**GHG Pollutants Expected to be Emitted, Annual Emission Rates, Global Warming Potential, and Annual Emissions Rates Adjusted for Global Warming Potential**

| Pollutant | Proposed Facility GHG Emissions (TPY) | Global Warming Potential (GWP) | GHG Emissions Adjusted for GWP (TPY) |
|---|---|---|---|
| Carbon Dioxide ($CO_2$) | 456,319 | 1 | 456,319 |
| Nitrous Oxide ($N_2O$) | 7.12 | 310 | 2,208 |
| Methane ($CH_4$) | 22.3 | 21 | 467 |
| Sulfur hexafluoride ($SF_6$) | 0.005 | 23,900 | 131 |
| Total GHG as $CO_2$e | ---- | ---- | 459,125 |

### 4.1.2 Other PSD Requirements

In accordance with EPA's March 2011 PSD and Tile V Permitting Guidance for GHGs , the following elements of PSD review are not required for GHG pollutants and therefore have not been included in this application: an impacts analysis; PSD additional impacts analysis; and GHG preconstruction monitoring analysis.

### 4.1.3 Federal Implementation Plan for Texas

EPA has determined that the Texas SIP is deficient for purposes of the PSD permitting of GHG. Accordingly, EPA adopted a FIP in which it retains the authority to issue a PSD permit for GHG. Thus, this application is being filed with EPA Region 6 for the sole purpose of obtaining a PSD permit for the emissions of GHG from the Bethel Energy Center. A permit for the emissions of the criteria and hazardous pollutants from Bethel Energy Center will be obtained from the State of Texas.

EPA has not adopted ambient air quality standards or finalized new source performance standards for GHG. Accordingly, this application only contains a BACT analysis for GHG.

### 4.1.4 New Source Review

PSD is the portion of NSR that applies to pollutants that are in attainment of National Ambient Air Quality Standards (NAAQS). Since there are no ambient air quality standards for GHG, major new or modified air emission sources are potentially subject to PSD review rather than non-attainment NSR review for GHG pollutants.

The first step in PSD review is determining whether the proposed facility is a major PSD source. As noted above, the Bethel Energy Center will be a major source. Therefore, Bethel Energy Center is subject to PSD review for GHG. The primary PSD requirement is application of BACT to emissions of GHG.

SECTION 5.0

# Greenhouse Gas BACT Analysis

## 5.1 Background

APEX plans to build a compressed air energy storage plant near the City of Tennessee Colony in Anderson County, Texas. The Bethel Energy Center will consist of a total of two natural gas-fired expansion turbine generators sized at a nominal 158.34-MW capacity each and will be equipped with low $NO_X$ burners with water injection and SCR for $NO_X$ control and Catalytic Oxidation for CO and VOC control. Bethel Energy Center auxiliary equipment includes two sets of mechanical draft wet cooling towers, one natural gas fired emergency generator engine, and an aqueous ammonia storage tank.

### 5.1.1 APEX Energy Storage Technology Selection

APEXs has determined that the proposed Dresser-Rand CAES technology is the only alternative that meets all of the Bethel Energy Center requirements for economic and reliable power 24 hours per day and in all weather conditions. Apex reached this determination on the basis of extensive economic analysis of all generating technology alternatives available for installation at a site within the ERCOT market.

## 5.2 Regulatory Basis

GHGs have become subject to emission permitting through PSD and Title V programs. On June 3, 2010, EPA issued the final Tailoring Rule (75 FR 31514), which allowed phasing in the PSD permitting process for new sources of GHGs such as the Bethel Energy Center. Step 2 of the Tailoring Rule requires that beginning July 1, 2011, all new sources with PTE greater than 100,000 tpy of GHGs on a $CO_2$e basis, and with a GHG PTE of 100 or 250 tpy, depending on source type, on a mass basis will become subject to PSD and Title V requirements. All references to tons within the table and in this BACT analysis are provided in terms of short tons (2,000 pounds/ton) instead of metric tonnes, in accordance with EPA GHG PSD permitting guidance.

The Bethel Energy Center will be a new source with a GHG PTE of greater than 100,000 tpy $CO_2$e. Because the TCEQ has a SIP-approved PSD program for all criteria pollutants but has not adopted regulations under the Tailoring Rule, TCEQ is the permitting authority for the Bethel Energy Center non-GHG pollutants (other regulated NSR pollutants), while EPA Region 6 is the permitting authority for the Bethel Energy Center GHG pollutants. Therefore, this GHG BACT analysis was prepared for presentation to EPA Region 6 as part of the Bethel Energy Center permit application process.

## 5.3 Emissions Summary

Per EPA Tailoring Rule definitions, GHGs consist of the following gases:

- Carbon Dioxide ($CO_2$)
- Methane ($CH_4$)
- Nitrous oxide ($N_2O$)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride ($SF_6$)

To determine $CO_2e$ emissions, mass flows of each individual gas emitted are multiplied by the appropriate Global Warming Potential (GWP) as referenced to the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report, and the results are summed.

The expansion turbine combustors will be fired with pipeline-quality natural gas, and complete combustion will result in water and $CO_2$ byproducts. However, incomplete combustion will result in some unburned natural gas or $CH_4$ emissions. Additionally, due to the presence of nitrogen in the combustion air, some small quantities of $N_2O$ will also be emitted.

The standby generator engine will be fired with natural gas, again resulting in $CO_2$ emissions from oxidation of the fuel, minor quantities of $CH_4$ emissions resulting from incomplete combustion, and $N_2O$ emissions from conversion of nitrogen from the atmosphere and fuel.

Fugitive emissions from equipment leaks consist of hydrocarbons, including $CH_4$, $CO_2$, and $SF_6$, which may be used as an insulating gas for high-voltage equipment and circuit breakers.

In addition, equipment maintenance activities may emit GHG during equipment purging prior to inspection and repairs. These emissions will consist primarily of $CH_4$ and other hydrocarbons.

Table 5-1 represents potential sources and estimated quantities of GHG emissions from the Bethel Energy Center equipment.

TABLE 5-1
**Bethel Energy Center Estimated GHG Emissions by Equipment Category**

| Equipment/Activity | Description | Total $CO_{2e}$ Emissions (t/yr) |
|---|---|---|
| Two (2) Expansion Turbine Trains | Maximum Heat Input Each 695.1 MMBtu/hr Higher Heating Value (HHV)** | **456,319** (including normal, startup, and shutdown operating conditions) |
| Fugitive Equipment Leaks | Weight percent of methane in gas stream 90.7 percent | **248** |
| One (1) Natural Gas-Fired Emergency Generator | Maximum Heat Input 7.78 MMBtu/hr | **23** |
| Facility Maintenance Activities | Emissions during purging of equipment prior to maintenance | **85** |
| **Total** | | **459,125** |

*** design maximum heat input to turbines was adjusted upward by 3% to account for equipment degradation between overhauls.*

## 5.3.1 GHG BACT Analysis Assumptions

During the completion of GHG BACT analysis, the following assumptions were made:

1. Table 5-1 presents the estimated Bethel Energy Center GHG emissions in terms of $CO_2e$ emissions, and only includes emissions of $CO_2$, $CH_4$, $N_2O$, and $SF_6$. The Bethel Energy Center is not expected to emit HFCs or PFCs because these manufactured gases are primarily used as cooling, cleaning, or propellant agents.

2. From the GHG emissions inventory presented in Appendix B, the relative quantities of $CH_4$, $N_2O$, and $SF_6$ total only approximately 2806 tpy of $CO_2e$, or less than 0.61 percent of total $CO_2e$ emissions. Due to the extremely small contribution of these three constituents to the total GHG emissions, the Bethel Energy Center GHG BACT analysis only included the five-step process for $CO_2$ emissions.

3. Installation of low $NO_X$ burners with water injection and an SCR system for $NO_X$ emissions reduction, and an oxidation catalyst for control of CO and VOCs for each expansion turbine train will be required to meet the

requirements of the TCEQ Standard Permit for EGUs and result in emissions below criteria pollutant PSD permitting thresholds.

4. During actual expansion turbine operation, the oxidation catalyst may result in minimal increases in $CO_2$ from the oxidation of any CO and $CH_4$ in the flue gas. However, the EPA Final Mandatory Reporting of Greenhouse Gases Rule (Mandatory Reporting Rule or MRR) (40 CFR 98) factors for estimating $CO_2$e emissions from the combustion of natural gas assume complete combustion of the fuel. While the oxidation catalyst has the potential of incrementally increasing $CO_2$ emissions, these emissions are already accounted for in the MRR factors and included in the $CO_2$e totals.

5. Similarly, the SCR catalyst may result in an increase in $N_2O$ emissions. Although quantifying the increase is difficult, it is generally estimated to be very small or negligible. From the GHG emissions inventory, the estimated $N_2O$ emissions from all combustion turbines total only 7.12 tpy. Therefore, even if there were an order–of-magnitude increase in $N_2O$ because of the SCR, the impact to total $CO_2$e emissions would be insignificant.

Use of the SCR and oxidation catalyst slightly decreases the Project thermal efficiency due to backpressure on the expansion turbines (these impacts are already included in the emission inventory) and, as noted above, may create a marginal but unquantifiable increase to $N_2O$ emissions. The expansion turbine SCR systems will be designed to reduce $NO_X$ from the expander low-$NO_X$ burners (LNBs) with water injection. Similarly, the oxidation catalyst systems have the benefit of reducing CO and VOC emissions.

While elimination of the $NO_X$ and CO/VOC controls could conceivably be considered as an option within the GHG BACT, the environmental benefits of the $NO_X$, CO, and VOC control are assumed to outweigh the marginal increase to GHG emissions. Thus, even if carried forward through the GHG BACT analysis, they would be eliminated in Step 4 due to other environmental impacts. *See* EPA's *PSD and Title V Permitting Guidance for Greenhouse Gases* (EPA, 2011). Therefore, we have not considered omission of these controls within the BACT analysis.

## 5.4 Top-Down BACT Process

The EPA has developed a recommended process for conducting BACT analyses, referred to as the "top-down" method. The following steps to conducting a top-down analysis are listed in the EPA's *New Source Review Workshop Manual* (EPA, 1990):

- Step 1: Identify all control technologies
- Step 2: Eliminate technically infeasible options
- Step 3: Rank remaining control technologies by control effectiveness
- Step 4: Evaluate most effective controls and document results
- Step 5: Select BACT

Each of these steps, described in the following sections, has been conducted for GHG emissions for the Bethel Energy Center. The following top-down BACT analysis for $CO_2$e has been prepared in accordance with the EPA's *New Source Review Workshop Manual* (EPA, 1990) and *PSD and Title V Permitting Guidance for Greenhouse Gases* (EPA, 2011). A top-down BACT analysis takes into account energy, environmental, economic, and other costs associated with each alternative technology.

# 5.5 Expansion Turbine BACT for GHGs

## 5.5.1 Step 1: Identify All Control Technologies

The expansion turbine generators will be nominal 158.34 MW machines that utilize the latest emissions control technology. There are two basic alternatives identified to limit the GHG emissions of the Project. These options include:

- Carbon Capture and Storage (CCS)
- Electrical Generation Conversion Efficiency

APEX has determined that the proposed Dresser-Rand CAES technology is the only alternative that meets all of the Bethel Energy Center requirements for economic operation within the ERCOT market. As such, other generation technologies such as coal, conventional gas-turbine based generation, reciprocating engines, wind, and solar were not evaluated in this BACT analysis. This is consistent with EPA's March 2011 *PSD and Title V Permitting Guidance for Greenhouse Gases,* which states, "EPA has recognized that a Step 1 list of options need not necessarily include inherently lower polluting processes that would fundamentally redefine the nature of the source proposed by the permit applicant…", and "…the permitting authority should keep in mind that BACT, in most cases, should not regulate the applicant's purpose or objective for the proposed facility…" (p. 26) Nonetheless, it should be noted that the Bethel Energy Center is intended to provide secure, reliable capacity to the grid, assisting the grid operator in coping with the intermittent nature of solar and wind generation, and renewable generation is not an effective supplement and backup for other renewable generation.

The only identified alternatives are post-combustion CCS and energy efficiency of the proposed generation facility.

## 5.5.2 Step 2: Eliminate Technically Infeasible Options

### Carbon Capture and Storage Systems

CCS systems involve use of adsorption or absorption processes to remove $CO_2$ from flue gas, with subsequent desorption to produce a concentrated $CO_2$ stream. The concentrated $CO_2$ is then compressed to "supercritical" temperature and pressure, a state in which $CO_2$ exists neither as a liquid nor a gas, but instead has physical properties of both liquids and gases. The supercritical $CO_2$ would then be transported to an appropriate location for underground injection into a suitable geological storage reservoir, such as a deep saline aquifer or depleted coal seam, or used in crude oil production for enhanced oil recovery.

The concentration of $CO_2$ is required because injection of exhaust streams containing high levels of nitrogen, oxygen and dilute $CO_2$ is not technically feasible. Research into technically and economically feasible capture systems is ongoing and is the focus of many large-scale grants from the DOE. Adequate techniques for compression of $CO_2$ exist, but such compression systems require large amounts of energy. Furthermore, the capture process is energy intensive. It is estimated that a significant portion of power plant output would be required for $CO_2$ capture and subsequent compression. As an example, as stated in the August 2010 *Report of the Interagency Task Force on Carbon Capture and Storage*, "For a [550 MWe net output] natural gas combined cycle (NGCC) plant, the capital cost would increase by $340 million and an energy penalty of 15 percent would result from the inclusion of $CO_2$ capture."

Research into geologic storage requirements is also ongoing. DOE research programs are investigating the reliability, permanence, risks, required monitoring, verification, and other issues to be addressed before geologic storage can proceed on a large commercial scale. Many regulatory issues remain to be resolved, such as pore space ownership, financial responsibility requirements, long-term risk following closure of the sequestration site, and issues regarding $CO_2$ purity and potential contamination of aquifers.

CCS systems are not currently available on a commercial basis. Large-scale demonstration projects are currently being planned or are in early stages of development, but no company or vendor currently offers a commercially available turn-key, integrated CCS system.

The Interagency Task Force on Carbon Capture and Storage consists of 14 executive departments and federal agencies, co-chaired by the DOE and EPA. As detailed in its August 2010 report, one goal of the task force is to bring five to 10 commercial demonstration projects online by 2016. With demonstration projects still years away, clearly the technology is not currently commercially available.

In the EPA PSD GHG permitting guidance, it is acknowledged that, "A number of ongoing research, development, and demonstration projects may make CCS technologies more widely applicable *in the future*" (italics added). "While CCS is a promising technology, EPA does not believe that at this time CCS will be a technically feasible BACT option in certain cases." As noted above, to establish that an option is technically infeasible, the permitting record should show that an available control option neither has been demonstrated in practice nor is available and applicable to the source type under review. EPA recognizes the significant logistical hurdles that the installation and operation of a CCS system presents, clearly distinguishing CCS from add-on control technologies that are typically used to reduce emissions of other regulated pollutants. Logistical hurdles for CCS may include obtaining contracts for offsite land acquisition (including the availability of land), the need for funding (including, for example, government subsidies), timing of available transportation infrastructure, and developing a site for secure long-term storage. Not every proposed project will have the resources to overcome the offsite logistical barriers necessary to apply CCS technology to its operations, and smaller sources will likely be especially constrained in this regard.

The Interagency Task Force report notes the lack of demonstration in practice: "Current technologies could be used to capture $CO_2$ from new and existing fossil energy power plants; however, they are not ready for widespread implementation primarily because they have not been demonstrated at the scale necessary to establish confidence for power plant application. Since the $CO_2$ capture capacities used in current industrial processes are generally much smaller than the capacity required for the purposes of GHG emissions mitigation at a typical power plant, there is considerable uncertainty associated with capacities at volumes necessary for commercial deployment."

Therefore, the CCS alternative is not considered technically feasible for the Bethel Energy Center, and is eliminated from further consideration. While it is being eliminated based on technical feasibility in Step 2, it should be acknowledged that even if carried forward for further analysis, it would undoubtedly be eliminated in Step 4 based on cost effectiveness. A qualitative cost analysis has been included in Step 4 to demonstrate the economic infeasibility.

EPA's *PSD and Title V Permitting Guidance for Greenhouse Gases* (EPA, 2011) identifies three categories of control alternatives (p. 25):

1. Inherently lower-emitting processes/practices/designs
2. Add-on controls
3. Combinations of lower-emitting process/practices/designs and add-on controls

Because there are no demonstrated add-on controls, only those processes, practices, and designs that result in lower GHG emissions are applicable for this BACT analysis.

### 5.5.3 Step 3: Rank Remaining Control Technologies by Control Effectiveness

Since CCS is eliminated in Step 2 as a technically infeasible control technology, the only remaining technology identified in Step 1 is energy efficiency. Since only one control technology remains at this step of the BACT analysis, ranking of numerous control technology options is not applicable.

### 5.5.4 Step 4: Evaluate Most Effective Controls and Document Results

As demonstrated in Step 2, CCS is not a technically feasible alternative for the Bethel Energy Center. Although not required, a high level qualitative analysis is presented below to demonstrate that even if CCS were technically feasible it would not be economically feasible. Following EPA's *PSD and Title V Permitting Guidance for Greenhouse Gases* (EPA, 2011), detailed cost estimates and vendor quotes have not been included: "With respect to the valuation of the economic impacts of GHG control strategies, it may be appropriate in some cases to assess the cost effectiveness of a control option in a less detailed quantitative (or even qualitative) manner. For instance, when evaluating the cost effectiveness of CCS as a GHG control option, if the cost of building a new pipeline to transport the $CO_2$ is extraordinarily high and by itself would be considered cost prohibitive, it would not be necessary for the applicant to obtain a vendor quote and evaluate the cost effectiveness of a $CO_2$ capture system."

The technical risks associated with the CCS technologies would make the Project un-financeable. The energy requirements for the capture and compression systems alone would dramatically increase the overall cost of the Project, and the capital cost of capture and compression systems, pipelines, development of storage reservoirs, and monitoring systems would be extraordinarily high as well.

As an example, the interagency task force report provides an estimate of capital costs for carbon capture from natural gas systems. It established a capital cost increase of $340 million and an energy penalty of 15 percent from the inclusion of $CO_2$ capture. This study was based on a 550 MWe net output natural gas combined cycle (NGCC) plant. Although the cost per megawatt would likely be higher for Bethel Energy Center due to the unique nature of the Project, this example is being used to demonstrate the order of magnitude of only the capital costs associated with the addition of $CO_2$ capture. Utilizing the "Capacity Factor Method" for prorating capital costs for similar systems of different sizes, the CO2 capture system capital cost for the Bethel Energy Center is estimated to be at least $244 million. The estimated total capital cost for this Project (not including CCS) is estimated at $350 million. This means the capital cost of the capture system alone would add approximately 70% to the overall capital cost of the Project.

Since CCS is clearly not economically feasible or technically feasible at this time, an evaluation of the remaining control technology under consideration, energy efficiency, is provided.

The Bethel Energy Center as proposed will utilize high-efficiency, state-of-the-art, CAES expansion turbines and associated combustors. Operation will use good combustion practices and good operating and maintenance practices to ensure complete combustion of the natural gas fuel. Additionally, insulation materials will be applied to minimize heat loss from the expanders, combustors, ducts, and the recuperator. Heat loss from the expanders and combustors will be further mitigated by the fact that these components will be housed within a building – i.e. not exposed to the elements.

Energy efficiency is normally expressed in terms of net heat rate. The Bethel turbine trains have an estimated net heat rate of 4,390 Btu/kWh at maximum load and 4,773 Btu/kWh at low load (HHV basis). These heat rate estimates incorporate an allowance for 3 percent performance degradation before performing each major inspection/overhaul. All performance figures for the Bethel Energy Center reflect Bethel Energy Center site conditions at 60°F.

As discussed earlier, for numerous reasons CAES expansion turbine technology is unique – and thus the assessment of BACT for GHG's for the Bethel Energy Center must be based on a comparison to the limited population of CAES installations. There are two CAES facilities in operation worldwide – McIntosh, in Alabama, and the Huntorf facility in Germany. Huntorf, completed in 1978, is a 290 MW facility designed and built by Brown Boveri Corporation (now a component of Asea Brown Boveri (ABB)). Huntorf was originally built to provide peaking power service, as well as black start capability for nuclear power units in the region. Today the plant has increasingly seen use to help balance wind generation in North Germany. Huntorf was constructed without a recuperator in order to minimize system start-up time.

McIntosh was placed in commercial operation in 1991 as a single train CAES facility, rated at 110 MW output. As discussed earlier, McIntosh used a novel "motor/generator", whereby a single electrical machine fulfilled dual roles as a motor for compressing, and as a generator when operating in the expansion mode. As with the Bethel Energy Center, the compression/expansion equipment at McIntosh was supplied by Dresser-Rand.

With regard to expander train design features, the high pressure (HP) and low pressure (LP) expanders and associated combustors at Bethel are very similar to the McIntosh equipment. The Bethel HP expander will operate at a higher full load inlet pressure than McIntosh (800 psia at Bethel vs. 630 psia at McIntosh). Additionally, the

Bethel combustors will use water injection for $NO_X$ control, whereas McIntosh does not use water injection. Finally, the recuperator at McIntosh was designed for an effectiveness of 75 percent compared to a design effectiveness of 90 percent for Bethel.

The application of a third expansion turbine at Bethel (the topping turbine) is an innovation driven by the much higher operating pressures of the Bethel cavern.

As shown in Table 5-2, the heat rate for the Bethel Energy Center represents a 31 percent improvement in comparison to Huntorf, and a 6 percent improvement in comparison to McIntosh. The design heat rate for Bethel (not adjusted for equipment degradation) was used for this computation, to be consistent with data available for the other two CAES installations.

The most important contributor to this heat rate improvement is the improved recuperator efficiency at Bethel. Other design changes have a meaningful impact on output (and hence capital cost on a $/kW basis) and specific air consumption, but they do not affect heat rate materially.

TABLE 5-2
**Comparison of CAES Installations**

| | **Output** | **Recuperator Efficiency** | **Heat Rate (at max load)** | **Number of Expanders** | **Cavern Operating Pressure Range** | **Hours of Storage (Full Load, No Recharge)** |
|---|---|---|---|---|---|---|
| Huntorf** | 290 MW | none installed | 6,175 Btu/kWh (HHV) | 2 | 700 – 970 psia | approximately 3 |
| McIntosh** | 110 MW (single CAES train installation) | 75 percent | 4,555 Btu/kWh (HHV) | 2 | 660 – 1,087 psia | approximately 25 |
| Bethel Energy Center | 317 MW (158.34 MW per train) | 90 percent | 4,262 Btu/kWh (HHV basis, prior to degradation) | 3 | 1,900 -- 2,830 psia | approximately 100 |

*** Data Source: Princeton University (April 2008).*

The heat rate advantage of the Bethel Energy Center documented in Table 5-2 above supports a determination that the Bethel Energy Center will have an energy conversion efficiency higher than CAES units currently in existence.

### 5.5.5 Step 5: Select BACT

The only technically feasible GHG control technology for the Bethel Energy Center is energy efficiency. Furthermore, the comparison provided in Section 5.5.4 demonstrates that the Bethel Energy Center will have a higher energy conversion efficiency than comparable CAES facilities. Consequently, the Bethel Energy Center as designed complies with GHG BACT requirements.

EPA's PSD permitting guidance for GHGs suggests use of output-based BACT emission limits and longer-term averaging periods for determining ongoing compliance. Based on APEXs' analysis of conservative operating scenarios, partial load operation, and turbine performance degradation, proposed BACT permit limits are provided in Table 5-3.

TABLE 5-3
**Bethel Energy Center Proposed BACT Limits**

| BACT Basis | Net Heat Rate (HHV) (Btu/kWh)* | Lb CO2/MW-hr* |
|---|---|---|
| Electrical Generation Efficiency* | 4,773 | 558 |

* At Bethel Energy Center site conditions, taking into account load fluctuations and performance degradation between overhauls

The calculation of the lb $CO_2$/MW-hr limit is provided in Appendix B and is based on the indicated estimated maximum heat rate, the load condition resulting in the highest $CO_2$ emissions per MW output, and an assumed 3 percent performance degradation between major equipment overhauls. The proposed averaging time for the compliance demonstration is a rolling 365 day period, consistent with other recently permitted power plants located in Texas.

## 5.6 Natural Gas Generator BACT for GHGs

In addition to the two combustion turbine trains planned for the Bethel Energy Center, one natural gas-fired emergency generator (nominal 1,053-BHP engine with estimated emissions of 23 $CO_2$e tpy) will operate at the plant. The GHG calculation for this source is located in Appendix B.

### 5.6.1 Step 1: Identify All Control Technologies

The available control technologies for the natural gas generator are identical to those identified for the combustion turbines. These options include

- Carbon Capture and Storage Systems (CCS)
- Generator Engine Efficiency
- Efficient Use of Energy
- Use of Clean Fuel

### 5.6.2 Step 2: Eliminate Technically Infeasible Options Effectiveness

#### Carbon Capture and Storage Systems

As discussed above, CCS for GHG control is not considered a technically feasible control option, due to CCS systems not currently available on a commercial basis, logistical hurdles, lack of demonstration in practice and cost of implementation. Therefore, CCS is eliminated from further consideration for natural gas generator engine GHG reduction.

#### Generator Engine Efficiency

The natural gas generator engine for the Bethel Energy Center will incorporate a high-efficiency design.

#### Efficient Use of Energy

The natural gas generator engine will not be operated continuously, but only during maintenance testing and during emergencies for backup power generation. Therefore, energy will be utilized in an efficient manner.

#### Use of Clean Fuel

The generator will use natural gas for fuel instead of diesel. The use of natural gas yields the lowest emissions of GHG.

### 5.6.3 Step 3: Rank Remaining Control Technologies by Control Effectiveness

The remaining technically feasible GHG control technologies for the Bethel Energy Center are "Generator Efficiency", "Efficient Use of Energy" and "Use of Clean Fuel." These technologies are equally important toward minimizing GHG emissions.

### 5.6.4 Step 4: Evaluate Most Effective Controls And Document Results

The remaining technically feasible GHG control technologies for the Bethel Energy Center are "Generator Efficiency", "Efficient Use of Energy" and "Use of Clean Fuel." All three technologies will be implemented for the generator engine.

### 5.6.5 Step 5: Select BACT

GHG BACT for the Bethel Energy Center natural gas generator is "Generator Efficiency", "Efficient Use of Energy" and "Use of Clean Fuel." The generator engine will be selected with consideration for high design efficiency, and will be operated in an efficient manner using natural gas fuel. Due to the estimated minor $CO_2e$ emissions contribution from the engine (only 0.005% of total GHG emissions), no BACT permit limit is recommended for the Bethel Energy Center natural gas generator.

## 5.7 Fugitive Emissions BACT for GHGs

In addition to the combustion sources planned for the Bethel Energy Center, there are natural gas emissions from leaking piping components, which include methane and CO2 emissions and $SF_6$ leaks from circuit breakers. Although this is a small source with an estimated 248 tpy $CO_2e$, for completeness, fugitive emissions are addressed in this BACT analysis. The GHG calculations for this source are located in Appendix B.

### 5.7.1 Step 1: Identify All Control Technologies

The available control alternatives for process fugitive emissions are as follows

- Use of a formal Leak Detection and Repair (LDAR) Program
- A Comprehensive Equipment Maintenance Program

### 5.7.2 Step 2: Eliminate Technically Infeasible Options Effectiveness

#### Use of LDAR

A formal LDAR program is a technically feasible option for controlling process fugitive GHG emissions.

#### Use of a Maintenance Program

A comprehensive equipment maintenance program is a technically feasible option for controlling process fugitive GHG emissions.

### 5.7.3 Step 3: Rank Remaining Control Technologies by Control Effectiveness

The remaining technically feasible GHG control technologies for the Bethel Energy Center are "LDAR" and "Maintenance Program."

### 5.7.4 Step 4: Evaluate Most Effective Controls and Document Results

#### LDAR

There are varied levels of stringency in LDAR programs for controlling VOC emissions. However, due to the small amount of GHG emissions from the fugitive sources, a formal LDAR program would not be considered for control of GHG emissions alone. As such, this evaluation does not compare the effectiveness of different levels of LDAR programs.

Although technically feasible, the use of an LDAR program to control the small amount of GHG emissions from the fugitive sources at the Bethel Energy Center is not cost effective.

Based on an estimate from an LDAR company, assuming that this site would be similar to a smaller gas plant subject to 40 CFR Part 60, Subpart KKK with around 600 quarterly components to monitor, the cost would be as follows:

- $16,000 for the first year, which includes tagging and initial monitoring
- $12,000 for annual monitoring

The above costs result in approximately $185 per ton of $CO_2$e removed. Although a fairly low cost per ton, based on the amount of tons reduced (approximately 78.9 tpy $CO_2$e, which is only 0.02% of total GHG emissions from the plant), this is not a cost effective program.

### Maintenance Program

Due to LDAR not being cost effective, a more reasonable choice for size and equipment at the Bethel Energy Center would be to apply a comprehensive equipment maintenance program. The maintenance program would include periodic inspections using auditory, visual, and olfactory (AVO) methods to find leaks. Leaks would be repaired in a reasonable time frame. Leaks and subsequent repairs would be documented. The cost of this program would be rolled into the facilities normal operation and maintenance costs of the facility.

## 5.7.5 Step 5: Select BACT

Based on the above analysis, BACT is determined to be a comprehensive equipment maintenance program. Due to the estimated minor $CO_2$e emissions contribution from fugitive emissions, no BACT permit limit is recommended for the Bethel Energy Center fugitive emissions.

SECTION 6.0
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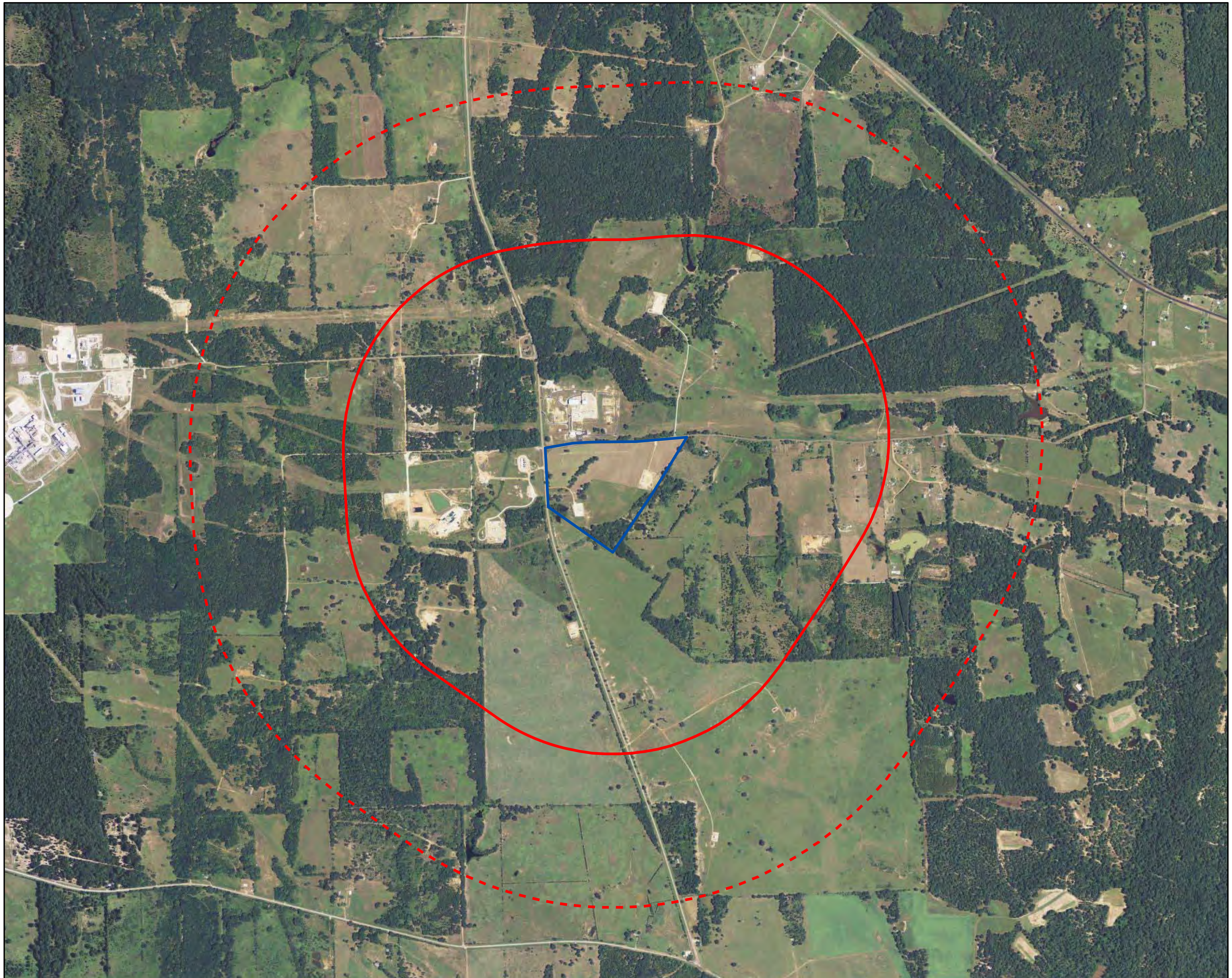
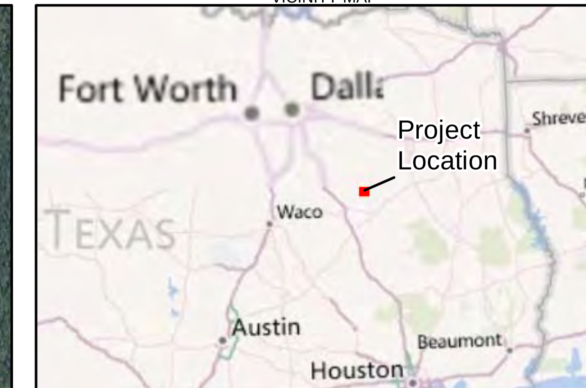
# Appendix A
# Location Map, Plot Plan, and Process Flow Diagram



VICINITY MAP




LEGEND

- Property Line
- One-Mile Radius
- 3,000-Foot Radius

Imagery Source: National Agriculture Imagery Program (NAIP), 2010.

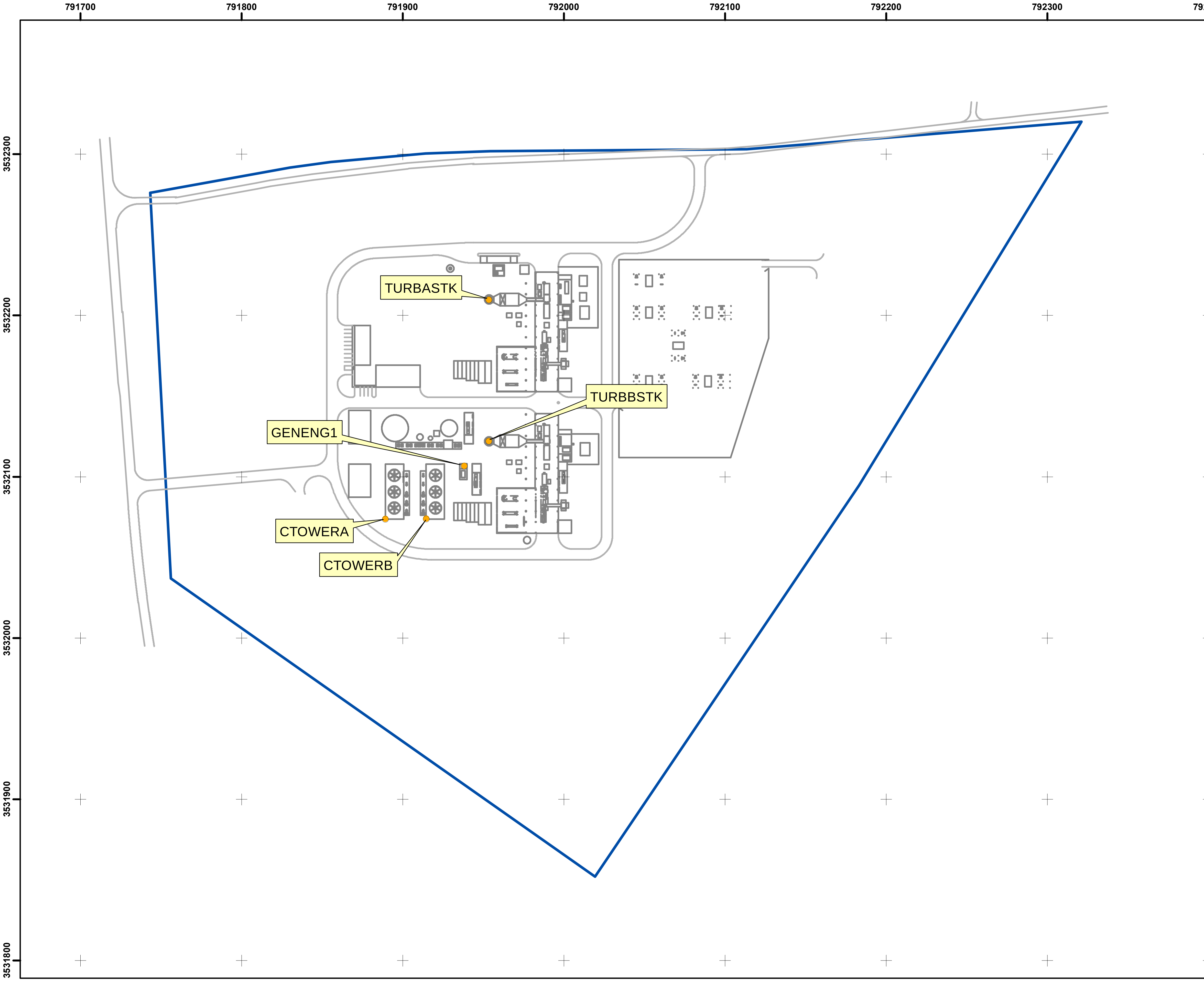
N

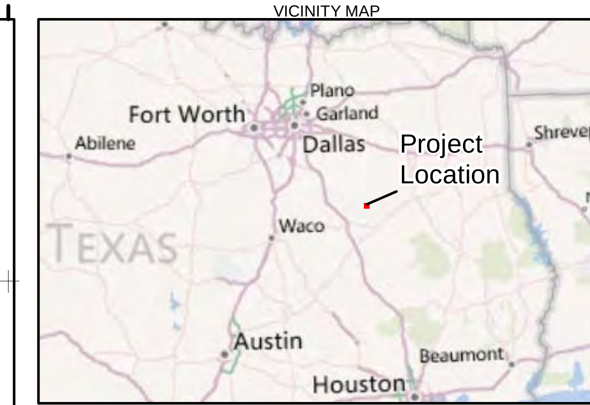
0 500 1,000
Feet

**APEX CAES Bethel Dome Site – Area Map**
*Anderson County, Texas*

CH2MHILL

UNK I:\APEX\GIS\MAPFILES\FIG1_AREA_MAP_11X17.MXD SCUTLER1 4/5/2012 3:08:06 PM




LEGEND

Property Line

Coordinate System:
UTM Zone 14, NAD83

0 100 200
Feet

**APEX Bethel Energy Center – Plot Plan**
*Anderson County, Texas*

DEN \\COBRA\PROJ\APEX\GIS\MAPFILES\FIG2_PLOT_PLAN_11X17_20120604.MXD LHEYERDA 6/12/2012 3:38:39 PM

CH2MHILL


| REV | DATE | BY | DESCRIPTION | CHK | ENGR | APPR | CLIENT |
|---|---|---|---|---|---|---|---|
| A | 05/21/12 | JH | ISSUE FOR PERMIT APPLICATION | | | | |

MUSTANG PROCESS AND INDUSTRIAL, INC.

PROJECT NO: 20406N
DESIGNED BY:
DRAWN BY: SDG 05MAY2012
CHECKED BY:
APPROVED BY:
SCALE: NTS DATE

Apex CAES

COMPRESSES AIR ENERGY STORAGE (CAES)

CAES OVERALL PROCESS FLOW DIAGRAM

DRAWING NO: PFD-001 REV: A

BASED ON DWG-ENG-1104 REV 2

# Appendix B
# Greenhouse Gas Supporting Documentation

# APEX Bethel Energy Center
## Greenhouse Gas Potential to Emit Emissions Summary

| APEX Bethel Energy Center Potential To Emit Greenhouse Gases | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CO2 | | CH4 | | N2O | | SF6 | | CO2-e | |
| | EPN | FIN | lb/hr | (English) tons/yr | lb/hr | (English) tons/yr | lb/hr | (English) tons/yr | lb/hr | (English) tons/yr | lb/hr | (English) tons/yr |
| *Maximum Operating Scenario with Federally Enforceable Limits:* | | | | | | | | | | | | |
| CAES Train A (1) | TURBASTK | TURBTRNA | --- | 222,552 | --- | 4.2 | --- | 0.42 | --- | --- | --- | 222,770 |
| CAES Train B (1) | TURBBSTK | TURBTRNB | --- | 222,552 | --- | 4.2 | --- | 0.42 | --- | --- | --- | 222,770 |
| Standby generator | GENENG1 | GENENG1 | 455 | 23 | 0.01 | 0.000 | 0.001 | 0.0000 | --- | --- | 455 | 23 |
| Cooling Tower A | CTOWERA | CTOWERA | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cooling Tower B | CTOWERB | CTOWERB | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CAES Startup A (2) | TURBASTK | TURBSUA | 29,430 | 5,371 | 11.66 | 2.127 | 17.21 | 3.1403 | --- | --- | 35,009 | 6,389 |
| CAES Startup B (2) | TURBBSTK | TURBSUB | 29,430 | 5,371 | 11.66 | 2.127 | 17.21 | 3.1403 | --- | --- | 35,009 | 6,389 |
| CAES Shutdown A (2) | TURBASTK | TURBSDA | 1,233 | 225 | 0.02 | 0.0042 | 0.002 | 0.00042 | --- | --- | 1,234 | 225 |
| CAES Shutdown B (2) | TURBBSTK | TURBSDB | 1,233 | 225 | 0.02 | 0.0042 | 0.002 | 0.00042 | --- | --- | 1,234 | 225 |
| Fugitives | FUG1 | FUG1 | --- | 0.2708 | --- | 5.56 | --- | --- | --- | 0.005 | --- | 248 |
| Maintenance | MAINT1 | MAINT1 | --- | 0.20 | --- | 4.03 | --- | --- | --- | --- | --- | 85 |
| | | | | | | | | | | | | |
| **Site-wide PTE with Federally Enforceable Limits (3)(4):** | | | | **456,319** | | **22.3** | | **7.12** | | **0.005** | | **459,125** |

**Assumptions:**

(1) CAES Train natural gas usage and air emissions presented above are distributed equally between the two trains. However, the distribution of natural gas may vary across the two trains but will not exceed the federally enforceable limit of 7,807,409 MMBtu/yr for both trains.

(2) Turbine startup/shutdown assumes 730 startups for 30 minutes each and 730 shutdowns for 3 minutes each

(3) Federally enforceable limit of 7,807,409 MMBtu/yr of combined natural gas usage at both CAES trains, 50 hours per year of emergency generator usage, 730 startups and 730 shutdowns per year for both CAES trains combined.

(4) Summary lb/hr emissions exclude Startup, Shutdown, and Maintenance Activities

## APEX Bethel Energy Center
## GHG Emission Calculations for Expansion Turbines under Normal Operating Conditions

**Natural Gas GHG Emissions, Maximum for One Train**

| Pollutant | Conversion Factor (kg to english tons) | Maximum Natural Gas Usage at 100% Load, One Train (MMBtu/yr) | Emission Factor (kg/MMBtu) | Emissions (english tons/year) | Global Warming Potential | ONE TRAIN<br>$CO_2$e (english tons/year) |
|---|---|---|---|---|---|---|
| $CO_2$ | 0.0011023 | 6,088,721 | 53.02 | 355,849 | 1 | 355,849 |
| $CH_4$ | 0.0011023 | 6,088,721 | 0.001 | 6.71 | 21 | 140.94 |
| $N_2O$ | 0.0011023 | 6,088,721 | 0.0001 | 0.67 | 310 | 208.06 |
| **Maximum TOTAL for One Train at 100% Load, 8760 hours/yr** | | | | | | 356,198 |

**Natural Gas GHG Emissions, Maximum for Both Trains Combined**

| Pollutant | Conversion Factor (kg to english tons) | Maximum Combined Annual Fuel Usage For Both Trains Under Normal Conditions (MMBtu/yr) (1) | Emission Factor (kg/MMBtu) | Emissions (english tons/year) | Global Warming Potential | TWO TRAINS<br>$CO_2$e (english tons/year) |
|---|---|---|---|---|---|---|
| $CO_2$ | 0.0011023 | 7,615,912 | 53.02 | 445,104 | 1 | 445,104 |
| $CH_4$ | 0.0011023 | 7,615,912 | 0.001 | 8.40 | 21 | 176.30 |
| $N_2O$ | 0.0011023 | 7,615,912 | 0.0001 | 0.84 | 310 | 260.25 |
| **Maximum Operating Scenario at Federally Enforceable Combined Fuel Limit, Both Trains:** | | | | | | **445,540** |

*GHG PSD Threshold = 100,000 tpy CO2-e*

| | | |
|---|---|---|
| **Maximum Combined Annual Fuel Usage For Both Trains Under Normal Conditions =** | **7,615,912** | **MMBtu/yr** |
| **Maximum Annual Fuel Usage For Both Trains Under Startup/Shutdown Conditions =** | **191,497** | **MMBtu/yr** |
| **TOTAL, Federally Enforceable Combined CAES Train Fuel Usage Limit (1) =** | **7,807,409** | **MMBtu/yr** |
| **Proposed BACT Limit in Units of lbs CO2/MW-hr (3) =** | **558** | **lbs CO2/MW-hr** |

**Proposed BACT Limit** **11% Load = 15.033 MW**

| Pollutant | Conversion Factor (kg to english tons) | 11% load 8760 Fuel Use (MMBtu/yr) (2) | Emission Factor (kg/MMBtu) | Emissions (metric tons/year) | Global Warming Potential | ONE TRAIN<br>CO2e (english tons/year) | BACT(3)<br>(lbs CO2/MWhr) |
|---|---|---|---|---|---|---|---|
| CO2 | 0.0011023 | 628,494 | 53.02 | 36,732 | 1 | 36,732 | 558 |
| CH4 | 0.0011023 | 628,494 | 0.001 | 0.69 | 21 | 15 | 0.2 |
| N2O | 0.0011023 | 628,494 | 0.0001 | 0.07 | 310 | 21 | 0.3 |
| | | | | | **TOTAL** | 36,768 | 558 |

**Assumptions:**
Each train contains (1) 158.34 MW rated generator consuming natural gas

**Equations and Example Calculations:**
(1) Federally enforceable combined natural gas usage limit of 7,807,409 MMBtu/yr for both CAES trains.
((158,338 kW at 100% load x 4390 btu/kWhr at 100% load x 4889 hours/year) + (24,529 kW at 15% load x 4531 btu/kWhr at 15% load x 3688 hours/year)) x 1 mmbtu/1000000 btu x 2 trains + Startup Fuel Usage + Shutdown Fuel Usage = 7,807,409 MMBtu/yr
(2) 15033 kw output per train at 11% load fuel rate x 4773 btu/kwhr x 1 mmbtu/1000000 btu x 8760 hr/yr = 628,494 mmbtu/yr)
(3) Proposed BACT limit (worst case lb CO2/MWhr rate at 11% load) = 36,732 english tons CO2/year x 1 year/8760 hours x 1/15.033 MW = 558 lbs CO2/MW-hr

**References:**
Heat rates (btu/kWhr) provided by manufacturer.
Emission factors obtained from EPA Mandatory GHG Reporting Rule, 40 CFR 98, Tables C-1 and C-2.

# APEX Bethel Energy Center
## GHG Emissions Calculations for Standby Emergency Generator Engine

*Standby Emergency Engine GHG Emissions Calculations - Startup, Maintenance, and Emergency Conditions (FIN/EPN: GENENG1)*

| FIN/EPN | Rating (ekW) | Rating at Maximum Load (bhp) | Annual 30-Min Events (Events/yr) | Annual Operation (1) (hr/yr) |
|---|---|---|---|---|
| GENENG1 | 740 | 1,053 | 100 | 50 |
| One (1) Standby Generator Set; Caterpillar G3516-SITA-130, 1200 rpm, 4-cycle, rich burn<br>Natural gas fired | | | | |
| **Constituents** | **Emission Factor** | | **Hourly Emissions 30-min duration** | **Annual Emissions** |
| | **Factor** | **Units** | **(lb/hr)** | **(ton/yr)** |
| **Criteria Pollutants** | | | | |
| CO2 | 53.02 | kg/MMBtu | 454.87 | 22.74 |
| CH4 | 0.001 | kg/MMBtu | 0.01 | 0.0004 |
| N2O | 0.0001 | kg/MMBtu | 0.001 | 0.0000 |
| CO2e | | | 455.32 | 22.77 |

**Assumptions:**

(1) Annual operation based on 50 hours per year which includes
- Monthly maintenance checks of 30 minutes duration = 6 hours per year
- Emergency operation

Hourly emissions are based on 30 minutes of emissions in one hour block of time.

Emissions are based on the operating load of the generator

Brake horsepower (bhp) is the power delivered directly to and measured at the engine's crankshaft; hp is the power delivered to and measured at the output shaft. The mechanical losses are accounted for in the % efficiency.

Engine uses NSCR to control NOx, CO, and VOC

**Constants:**

| | |
|---|---|
| 7391 | btu/bhp-hr Brake Specific Fuel Consumption (BSFC) per Caterpillar spec sheet (8600 scf/hr fuel gas flow/1053 bhp x 905 btu/scf fuel heat value at the specified rating) |
| 2.20462 | lb/kg |
| 1 | Global Warming Potential for CO2 |
| 21 | Global Warming Potential for CH4 |
| 310 | Global Warming Potential for N2O |

**Equations and Example Calculations:**

CO2 Hourly Emissions (lb/hr) = Engine Rating (bhp) x BSFC (btu/bhp-hr) x CO2 EF (kg/mmbtu) x Conversion (2.20462 lb/1 kg) x Operating Time (0.5 hr/hr) = CO2 (lb/hr)

CO2 Hourly Emissions (lb/hr) = 1053 (bhp) x 7391 (btu/bhp-hr) x 53.02 (kg/mmbtu) x Conversion (2.20462 lb/1 kg) x Operating Time (0.5 hr/hr) = 454.87 (lb/hr)

CO2 Annual Emissions(tpy) = CO2 Emissions (lb/hr) x Maximum Hours of Operation (hr/yr) x Conversion (1 ton/2000 lb) = CO2 (tpy)

CO2 Annual Emissions(tpy) = 454.87 (lb/hr) x 50 (hr/yr) x Conversion (1 ton/2000 lb) = 22.74 (tpy)

CO2e Hourly Emissions (lb/hr) = CO2 Hourly Emissions (lb/hr) x GWP CO2 (lb CO2e/ lb CO2) + CH4 Hourly Emissions (lb/hr) x GWP CH4 (lb CO2e/lb CH4) + N2O Hourly Emissions (lb/hr) x GWP N2O (lb CO2e/lb N2O) = CO2e lb/hr

**References:**

| | |
|---|---|
| CO2 based on | Emission factors as per 40 CFR Part 98, Table C-1 |
| $CH_4$ based on | Emission factors as per 40 CFR Part 98, Table C-2 |
| $N_2O$ based on | Emission factors as per 40 CFR Part 98, Table C-2 |
| CO2-e based on | CO2 equivalent (CO2-e) Emission factors as per 40 CFR Part 98, Tables C-1 and C-2 which are based on the summation of CO2, CH4, and N2O emissions |

## APEX Bethel Energy Center
## GHG Emissions Calculations for Turbine Startup Events

### *Turbine Startup (SU) Events GHG Emissions Calculations (FIN: TURBSUA and TURBSUB; EPN: TURBASTK and TURBBSTK)*

***Data provided per train unless stated otherwise***

| EPN | NG Fuel Flowrate at 50% Load Per Train (mmbtu/hr) | Duration of Time at 50% Load (minutes per hour) | NG Fuel Flowrate at 100% Load Per Train (mmbtu/hr) | Duration of Time at 100% Load (minutes per hour) | Annual Operation For Both Trains (events/yr) | Annual NG Usage for Startups MMBtu/yr |
|---|---|---|---|---|---|---|
| TURBSTK | 312.04 | 15 | 695.06 | 15 | 730 | 183,796 |

One train includes natural gas demand for HP combustor, LP combustor, and topping turbine
Natural gas fired

| Constituents | Emission Factor | | Hourly Emissions (lb/event) | Annual Emissions (ton/yr) |
|---|---|---|---|---|
| | Factor | Units | | |
| CO2 | 53.02 | kg/mmbtu | 29,430 | 10,742 |
| CH4 | 0.001 | kg/mmbtu | 11.66 | 4.25 |
| N2O | 0.0001 | kg/mmbtu | 17.21 | 6.28 |
| CO2e | | | 35,009 | 12,778 |

**Assumptions:**

Calculations based on start to full load in 30 minutes
Assumes 365 startups per year for each train.

**Constants:**

| | |
|---|---|
| 21496 | Btu/lb LHV per Dresser-Rand |
| 23839 | Btu/lb HHV per Dresser-Rand |
| 1044 | btu/scf at HHV per Dresser-Rand |
| 2.20462 | lb/kg |
| 1 | Global Warming Potential for CO2 |
| 21 | Global Warming Potential for CH4 |
| 310 | Global Warming Potential for N2O |

**Equations and Example Calculations:**

CO2 Hourly Emissions (lb/event) = NG Fuel Flowrate at 50% Load Per Train (mmbtu/hr) x CO2 EF (kg/mmbtu) x Conversion (2.20462 lb/1 kg) x duration of event (15 min/event) x Conversion (1hr/60min) + NG Fuel Flowrate at 100% Load Per Train (mmbtu/hr) x CO2 EF (kg/mmbtu) x Conversion (2.20462 lb/1 kg) x duration of event (15 min/event) x Conversion (1hr/60min) = CO2 (lb/event)

CO2 Annual Emissions (tpy) = CO2 Hourly Emissions per Event (lb/event) x Events Per year (count) x Conversion (1 ton/2000 lb) = CO2 tpy

CO2e Hourly Emissions (lb/hr) = CO2 Hourly Emissions (lb/hr) x GWP CO2 (lb CO2e/ lb CO2) + CH4 Hourly Emissions (lb/hr) x GWP CH4 (lb CO2e/lb CH4) + N2O Hourly Emissions (lb/hr) x GWP N2O (lb CO2e/lb N2O) = CO2e lb/hr

**References:**

| | |
|---|---|
| CO2 based on | Emission factors as per 40 CFR Part 98, Table C-1 |
| $CH_4$ based on | Emission factors as per 40 CFR Part 98, Table C-2 |
| $N_2O$ based on | Emission factors as per 40 CFR Part 98, Table C-2 |
| CO2-e based on | CO2 equivalent (CO2-e) Emission factors per 40 CFR Part 98, Tables C-1 and C-2 which are based on the sum of CO2, CH4, and N2O emissions |

# APEX Bethel Energy Center
## GHG Emissions Calculations for Turbine Shutdown Events

### *Turbine Shutdown (SD) Events GHG Emissions Calculations (FIN: TURBSDA and TURBSDB; EPN: TURBASTK and TURBBSTK)*

***Data provided per train unless stated otherwise***

| Name of Unit | Number of Trains | NG Fuel Flowrate at 25% Load Per Train (mmbtu/hr) | Duration of Time in 1-hr minutes per hour | Annual Operation For Both Trains (events/yr) | Annual NG Usage for Shutdowns MMBtu/yr |
|---|---|---|---|---|---|
| TURBSTK | 2 | 191.81 | 3.3 | 730 | 7,701 |

| Constituents | Emission Factor | | Hourly Emissions (lb/event) | Annual Emissions (ton/yr) |
|---|---|---|---|---|
| | Factor | Units | | |
| CO2 | 53.02 | kg/mmbtu | 1233.12 | 450.09 |
| CH4 | 0.001 | kg/mmbtu | 0.02 | 0.0085 |
| N2O | 0.0001 | kg/mmbtu | 0.002 | 0.00085 |
| CO2e | | | 1234.33 | 450.53 |

**Assumptions:**

Assumes 365 shutdowns per year for each train.
Assumes 25% Load during the duration of the shutdown.

**Constants:**

| | |
|---|---|
| 21496 | Btu/lb LHV per Dresser-Rand |
| 23839 | Btu/lb HHV per Dresser-Rand |
| 1044 | btu/scf at HHV per Dresser-Rand |
| 2.20462 | lb/kg |
| 1 | Global Warming Potential for CO2 |
| 21 | Global Warming Potential for CH4 |
| 310 | Global Warming Potential for N2O |

**Equations and Example Calculations:**

CO2 Hourly Emissions (lb/event) = NG Fuel Flowrate at 25% Load Per Train (mmbtu/hr) x CO2 EF (kg/mmbtu) x Conversion (2.20462 lb/1 kg) x duration of event (3.3 min/event) x Conversion (1hr/60min) = CO2 (lb/event)

CO2 Annual Emissions (tpy) = CO2 Hourly Emissions per Event (lb/event) x Events Per year (count) x Conversion (1 ton/2000 lb) = CO2 tpy
CO2e Hourly Emissions (lb/hr) = CO2 Hourly Emissions (lb/hr) x GWP CO2 (lb CO2e/ lb CO2) + CH4 Hourly Emissions (lb/hr) x GWP CH4 (lb CO2e/lb CH4) + N2O Hourly Emissions (lb/hr) x GWP N2O (lb CO2e/lb N2O) = CO2e lb/hr

**References:**

| | |
|---|---|
| CO2 based on | Emission factors as per 40 CFR Part 98, Table C-1 |
| $CH_4$ based on | Emission factors as per 40 CFR Part 98, Table C-2 |
| $N_2O$ based on | Emission factors as per 40 CFR Part 98, Table C-2 |
| CO2-e based on | CO2 equivalent (CO2-e) Emission factors as per 40 CFR Part 98, Tables C-1 and C-2 which are based on the summation of CO2, CH4, and N2O emissions |

## APEX Bethel Energy Center
## GHG Emissions Calculations for Equipment Leak Fugitives

### *Fugitives Emissions Calculations (FIN/EPN: FUG1)*

| Fugitive Emissions | lbs/hr | TPY |
|---|---|---|
| $CO_2$ | 0.062 | 0.271 |
| $CH_4$ | 1.270 | 5.563 |
| CO2e | 26.735 | 117.098 |

| Emissions Source | Emission Factor [1] | Units | Number | Emissions, lb/hr | Emissions, TPY | % CO2 [2] | CO2, lb/hr | CO2, TPY | % CH4 [2] | CH4, lb/hr | CH4, TPY | CO2e, lb/hr | CO2e, TPY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Valves | | | | | | | | | | | | | |
| Gas | 0.00992 | lb/hr/component | 110 | 1.09 | 4.78 | 4.413% | 0.0482 | 0.211 | 90.656% | 0.99 | 4.33 | 20.82 | 91.202 |
| Heavy Oil | 0.0000185 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Light Oil | 0.0055 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Aqueous Ammonia/Water/Light Oil | 0.000216 | lb/hr/component | 33 | 0.007 | 0.031 | 100% NH3 | -- | -- | 100% NH3 | -- | -- | -- | -- |
| Pumps | | | | | | | | | | | | | |
| Gas | 0.00529 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Heavy Oil | 0.00113 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Light Oil | 0.02866 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Aqueous Ammonia/Water/Light Oil | 0.0000529 | lb/hr/component | 2 | 0.0001 | 0.0005 | 100% NH3 | -- | -- | 100% NH3 | -- | -- | -- | -- |
| Flanges | | | | | | | | | | | | | |
| Gas | 0.00086 | lb/hr/component | 268 | 0.2305 | 1.0095 | 4.413% | 0.0102 | 0.0446 | 90.656% | 0.21 | 0.92 | 4.40 | 19.26332 |
| Heavy Oil | 0.00000086 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Light Oil | 0.000243 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Aqueous Ammonia/Water/Light Oil | 0.00000617 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Connectors | | | | | | | | | | | | | |
| Gas | 0.00044 | lb/hr/component | 4 | 0.00 | 0.01 | 4.413% | 0.0001 | 3.40E-04 | 90.656% | 0.002 | 0.007 | 0.03 | 0.147099 |
| Heavy Oil | 0.0000165 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Light Oil | 0.000463 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Aqueous Ammonia/Water/Light Oil | 0.000243 | lb/hr/component | 2 | 0.0005 | 0.0021 | 100% NH3 | -- | -- | 100% NH3 | -- | -- | -- | -- |
| Open-Ended Lines | | | | | | | | | | | | | |
| Gas | 0.00441 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Heavy Oil | 0.000309 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Light Oil | 0.00309 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Aqueous Ammonia/Water/Light Oil | 0.0006 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Other/Compressors/Relief Valves/Process Drains | | | | | | | | | | | | | |
| Gas | 0.0194 | lb/hr/component | 4 | 0.08 | 0.34 | 4.413% | 0.0034 | 1.50E-02 | 90.656% | 0.07 | 0.31 | 1.48 | 6.49E+00 |
| Heavy Oil | 0.0000683 | lb/hr/component | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Light Oil | 0.0165 | lb/hr/component | 2 | 0.033 | 0.145 | 100% VOC | -- | -- | 100% VOC | -- | -- | -- | -- |
| Aqueous Ammonia/Water/Light Oil | 0.0309 | lb/hr/component | 0 | 0 | 0 | | | | | | | | |
| **TOTAL** | | | | **1.43** | **6.3** | | **0.062** | **0.271** | | **1.270** | **5.563** | **26.73** | **117.10** |

| Gas Analysis | MW | Mole % | Equivalent Weight | Weight % |
|---|---|---|---|---|
| Nitrogen | 28.0134 | 0.912% | 0.255 | 1.51% |
| Carbon dioxide | 44.01 | 1.696% | 0.75 | 4.4% |
| Hydrogen sulfide | 34.08 | 0% | 0 | 0% |
| Methane | 16.043 | 95.549% | 15.3 | 90.7% |
| Ethane | 30.07 | 1.729% | 0.52 | 3.08% |
| Propane | 44.097 | 0.079% | 0.035 | 0.207% |
| Isobutane | 58.1222 | 0.011% | 0.006 | 0.037% |
| n-Butane | 58.1222 | 0.011% | 0.006 | 0.037% |
| Isopentane | 72.1488 | 0.004% | 0.003 | 0.019% |
| n-Pentane | 72.1488 | 0.002% | 0.002 | 0.010% |
| Cyclopentane | 70.1329 | 0.000% | 0.000 | 0.000% |
| n-Hexane | 86.1754 | 0.000% | 0.000 | 0.000% |
| Cyclohexane | 84.1595 | 0.000% | 0.000 | 0.000% |
| Other C6's | 86 | 0.007% | 0.006 | 0.035% |
| Heptanes | 100.2019 | 0.000% | 0.000 | 0.000% |
| Methylcyclohexane | 98.1861 | 0.000% | 0.000 | 0.000% |
| Benzene | 78.1118 | 0.000% | 0.000 | 0.000% |
| Toluene | 92.1384 | 0.000% | 0.000 | 0.000% |
| Ethylbenzene | 106.165 | 0.000% | 0.000 | 0.000% |
| Xylenes | 106.165 | 0.000% | 0.000 | 0.000% |
| Octanes Plus | 114.23 | 0.000% | 0.000 | 0.000% |
| VOC | | 0.11% | | 0.34% |
| HAPs | | 0.00% | | 0.00% |
| **TOTAL** | | 100% | 16.9 | 100% |

**Assumptions:**

Fuel speciation provided by gas analysis on 12/28 2011 at Analyzer Bethe SN: 9004355 SO: 190594

Energy Transfer Company estimates 26 valves and 64 flanges at the gas metering stations

Per Mustang Engineering preliminary design estimates on the natural gas supply line, there are approximately 84 valves, 102 sets (pairs) of flanges, four PSVs, and four connectors

**Constants:**

1 Global Warming Potential for CO2

21 Global Warming Potential for CH4

**Equations and Example Calculations:**

CO2 Hourly Emissions (lb/hr) = Number of Components x Component Emission Factor (lb/hr/component) x VOC Weight Percent (wt. %) = CO2 lb/hr

CO2 Annual Emissions Per Train (tpy) = CO2 Emissions (lb/hr) x Conversion (1 ton/2000 lb) x Annual Operation (8760 hr/yr) = CO2 (tpy)

CO2e Hourly Emissions (lb/hr) = CO2 Hourly Emissions (lb/hr) x GWP CO2 (lb CO2e/ lb CO2) + CH4 Hourly Emissions (lb/hr) x GWP CH4 (lb CO2e/lb CH4) = CO2e lb/hr

CO2e Annual Emissions Per Train (tpy) = CO2e Emissions (lb/hr) x Conversion (1 ton/2000 lb) x Annual Operation (8760 hr/yr) = CO2e (tpy)

**References:**


(1) TCEQ. January 2008. *Emissions Factors for Equipment Leak Fugitive Components Addendum to RG-360A*, Table 4 for Oil and Gas Production Operations.

(2) From gas analysis

# APEX Bethel Energy Center
# GHG Emissions Calculations for Circuit Breakers

### *Circuit Breaker Fugitive Emissions Calculations*

| Emissions | lbs/hr | TPY |
|---|---|---|
| SF6 | 0.001 | 0.01 |
| CO2e | 29.88 | 130.85 |

| | Value | Units |
|---|---|---|
| | | |
| 345 kV, 2000A, 1300 BIL Breaker | | |
| lb SF6 per breaker | 365 | |
| Number of breakers | 6 | |
| Leak Rate, % by weight | 0.5 | |
| Global Warming Potential (1) | 23900 | |
| | | |
| SF6 emission rate | 10.95 | lb/yr |
| | 0.00125 | lb/hr |
| | 0.0055 | ton/yr |
| | | |
| CO2e emission rate | 261,705 | lb/yr |
| | 29.88 | lb/hr |
| | 130.85 | ton/yr |

*1. Global Warming Potential factors based on Table A-1 of 40 CFR 98 Mandatory Greenhouse Gas Reporting.*

**Assumptions:**

365 pounds of SF6 for each 345 kV circuit breaker

**Equations and Example Calculations:**

SF6 annual emissions (lb/yr) = lb SF6 per breaker (lb/breaker) x Number of breakers (count) x Leak Rate (wt%/yr) x Conversion (1/100%) = SF6 lb/yr

SF6 annual emissions (lb/yr) = 365 (lb/breaker) x 6 (count) x 0.5 (wt%/yr) x Conversion (1/100%) = 10.95 SF6 lb/yr

SF6 hourly emissions (lb/hr) = SF6 annual emissions (lb/yr) x Conversion (yr/8760hr) = SF6 lb/hr

SF6 hourly emissions (lb/hr) = 10.95 (lb/yr) x Conversion (yr/8760hr) = 0.00125 lb/hr

SF6 annual emissions (ton/yr) = 10.95 (lb/yr) x Conversion (ton/2000 lb) = 0.0055 ton/yr

CO2e annual emissions (ton/yr) = SF6 annual emissions (ton/yr) x GWP (ton CO2e/ton SF6) = CO2e ton/yr

CO2e annual emissions (ton/yr) = 0.0055 (ton/yr) x 23900 (ton CO2e/ton SF6) = 130.85 ton/yr

## APEX Bethel Energy Center
## GHG Emissions Calculations from Facility Maintenance Activities

### *Maintenance Emissions Calculations (FIN/EPN: MAINT1)*

| Emission Unit Data | Value | Units | Source |
|---|---|---|---|
| Maximum Vent Rate | 113 | cf/hr | Depressurizing of NG supply line from metering station to CAES train as worst case at 1100 PSIG and 25C. |
| Maximum Vent Rate | 8,435 | scf/hr | Conversion to Std. Conditions (68F, 14.7 psia) |
| Average Maintenance Event Frequency | 1 | vent/month | Estimate per train |
| Conversion Factor | 385 | dscf/lbmole | Std. Conditions (68F, 14.7 psia) |
| Number of Trains at the Site | 2 | | |

Planned maintenance activities involve depressurizing and breaking lines to access instrumentation and ancillary equipment for periodic planned maintenance. Therefore, the majority of emissions are a result of venting the pressurized line to atmosphere. The length of line to depressurize is minimized by valving off the section needed for access.

| Gas Analysis | MW | Mole % | Equivalent Weight | Weight % |
|---|---|---|---|---|
| Nitrogen | 28.0134 | 0.912% | 0.255 | 1.51% |
| Carbon dioxide | 44.01 | 1.696% | 0.75 | 4.41% |
| Hydrogen sulfide | 34.08 | 0% | 0 | 0.00% |
| Methane | 16.043 | 95.549% | 15.3 | 90.66% |
| Ethane | 30.07 | 1.729% | 0.52 | 3.08% |
| Propane | 44.097 | 0.079% | 0.035 | 0.21% |
| Isobutane | 58.1222 | 0.011% | 0.006 | 0.04% |
| n-Butane | 58.1222 | 0.011% | 0.006 | 0.04% |
| Isopentane | 72.1488 | 0.004% | 0.003 | 0.02% |
| n-Pentane | 72.1488 | 0.002% | 0.002 | 0.01% |
| Cyclopentane | 70.1329 | 0.000% | 0.000 | 0.00% |
| n-Hexane | 86.1754 | 0.000% | 0.000 | 0.00% |
| Cyclohexane | 84.1595 | 0.000% | 0.000 | 0.00% |
| Other C6's | 86 | 0.007% | 0.006 | 0.03% |
| Heptanes | 100.2019 | 0.000% | 0.000 | 0.00% |
| Methylcyclohexane | 98.1861 | 0.000% | 0.000 | 0.00% |
| Benzene | 78.1118 | 0.000% | 0.000 | 0.00% |
| Toluene | 92.1384 | 0.000% | 0.000 | 0.00% |
| Ethylbenzene | 106.165 | 0.000% | 0.000 | 0.00% |
| Xylenes | 106.165 | 0.000% | 0.000 | 0.00% |
| Octanes Plus | 114.23 | 0.000% | 0.000 | 0.00% |
| VOC | 51 | 0.11% | | 0.34% |
| HAPs | | 0.00% | | 0.00% |
| Total | | 100.00% | 16.9 | 100% |

| Emissions For Both Trains | lb/hr | TPY |
|---|---|---|
| CO2 | 16.35 | 0.20 |
| CH4 | 335.83 | 4.03 |
| CO2e | 7068.82 | 84.83 |

**Assumptions:**

Fuel speciation provided by gas analysis on 12/28 2011 at Analyzer Bethe SN: 9004355 SO: 190594

The maximum vent rate is based upon depressurizing the natural gas supply line from the Energy Transfer metering station tie-point to the CAES Train HP/LP expanders.

Assumes the NG supply pipe is six inches in diameter (Schedule 80 pipe ID 5.761 inches, area 0.181 ft2) and 625 feet long to provide a volume of 113.1 ft3 at 1100 PSIG and 25C. Converting this to Standard Conditions (68 F and 14.696 PSIA) yields a result of 8435 scf/hr.

Assumes vent occurs within a one-hour period.

**Constants:**

| | |
|---|---|
| 0.585 | SG of natural gas per Dresser-Rand |
| 21496 | Btu/lb LHV per Dresser-Rand |
| 23839 | Btu/lb HHV per Dresser-Rand |
| 1 | Global Warming Potential for CO2 |
| 21 | Global Warming Potential for CH4 |

**Equations and Example Calculations:**

CO2 Hourly Emissions for One Train (lb/hr) = Maximum Vent Rate (scf/hr) x Conversion Factor (lbmol/dscf) x CO2 mole % in Vent (mole %) x MW of CO2 (lb/lbmole) = CO2 lb/hr

CO2 Annual Emissions For Both Trains (tpy) = CO2 Emissions (lb/hr) x Conversion (1 ton/2000 lb) x Annual Operation (1 event/month) x Conversion (12 month/1 yr) x Number of Trains at Site = CO2 (tpy)

CO2e Hourly Emissions (lb/hr) = CO2 Hourly Emissions (lb/hr) x GWP CO2 (lb CO2e/ lb CO2) + CH4 Hourly Emissions (lb/hr) x GWP CH4 (lb CO2e/lb CH4) = CO2e lb/hr

# Appendix C
# Permit Application Forms

# Texas Commission on Environmental Quality
# Form PI-1S
# Registrations for Air Standard Permit
# (Page 1)

| | |
|---|---|
| **I. Registrant Information** | |
| **A. Is a TCEQ Core Data Form (TCEQ Form No. 10400) attached?**<br>**Core Data Form required for Standard Permits 6004, 6006, 6007, 6008, and 6013.** | ☐ YES ☒ NO |

**Customer Reference Number (CN):** Not yet assigned.

**Regulated Entity Number (RN):** Not yet assigned.

**B. Company or Other Legal Customer Name (must be same as Core Data "Customer"):**

APEX Bethel Energy Center, LLC

**Company Official Contact Name:** Stephen Naeve

**Title:** Chief Operating Officer

**Mailing Address:** 3200 Southwest Freeway, Suite 2210

| | | |
|---|---|---|
| **City:** Houston | **State:** TX | **ZIP Code:** 77027 |
| **Phone No.:** (713) 963-8104 | **Fax No.:** | **E-mail Address:** Stephen.naeve@apexcaes.com |

**C. Technical Contact Name:** Ashley Campsie/ CH2M HILL

**Title:** Environmental Engineer

**Mailing Address:** 9191 South Jamaica Street

| | | |
|---|---|---|
| **City:** Englewood | **State:** CO | **ZIP Code:** 80112 |
| **Phone No.:** (720) 286-1236 | **Fax No.:** (720) 286-8187 | **E-mail Address:** Ashley.Campsie@ch2m.com |

**D. Facility Location Information (Street Address):**

**If no street address, provide clear driving directions to the site in writing:**

Intersection of County Rd. 2504 and F.M. 2706

| | | |
|---|---|---|
| **City:** Tennessee Colony | **County:** Anderson | **ZIP Code:** 75861 |

| | |
|---|---|
| **Latitude (nearest second):** 31.887725 N | **Longitude (nearest second):** -95.913241 W |

**II. Facility and Site Information**

| | |
|---|---|
| **A. Name and Type of Facility:** APEX Bethel Energy Center | ☒ Permanent ☐ Portable |

| | | | |
|---|---|---|---|
| **B. Type of Action:** | ☒ Initial Application | ☐ Renewal | ☐ Change to Registration |
| | Registration No.: | | ☐ Expiration Date: |

**C. List the Standard Permit Claimed:**

**Description:** Electric Generating Unit (EGU) Standard Permit

**D. Concrete Batch Plant Standard Permit *(Check one)*** N/A

☐ Central Mix ☐ Ready Mix ☐ Specialty Mix ☐ Enhanced Controls for Concrete Batch Plants

**Texas Commission on Environmental Quality**
**Registrations for Air Standard Permit**
**PI-1S**
**(Page 2)**

| | |
|---|---|
| **II. Facility and Site Information *(continued)*** | |
| **E. Proposed Start of Construction:** 1st Q 2013 | **Length of Time at the Site:** New Site |
| **Customer Reference No.:** TBD | **Regulated Entity No.:** TBD |
| **F. Is there a previous Standard Exemption or Permit by Rule for the facilities in this registration? *(Attach details regarding changes)*** | ☐ YES ☒ NO |
| **If "YES," list Permit No.:** | |
| **G. Are there any other facilities at this site which are authorized by an air Standard Permit?** | ☐ YES ☒ NO |
| **If "YES," list Permit No.:** | |
| **H. Are there any other air preconstruction permits at this site?** | ☒ YES ☐ NO |
| **If "YES," list Permit No.:** GHG PSD Permit, to be issued by EPA Region 6 | |
| **Are there any other air preconstruction permits at this site that would be directly associated with this project?** | ☒ YES ☐ NO |
| **If "YES," list Permit No.:** GHG PSD Permit, to be issued by EPA Region 6 | |
| **I. TCEQ Account Identification Number (if known):** TBD | |
| **J. Is this facility located at a site which is required to obtain a federal operating permit pursuant to 30 TAC Chapter 122?** | ☐ YES ☐ NO ☒ To Be Determined |

| | | |
|---|---|---|
| **K. Identify the requirements of 30 TAC Chapter 122 that will be triggered if this Form PI-1S application is approved.** | | |
| ☐ Application for an FOP | ☐ FOP Significant Revision | ☐ FOP Minor |
| ☐ Operational Flexibility/Off-Permit Notification | ☐ Streamlined Revision for GOP | |
| ☒ To Be Determined | ☐ None | |
| **L. Identify the type(s) issued and/or FOP application(s) submitted/pending for the site. *(check all that apply)*** | | |
| ☐ SOP | ☐ GOP | ☐ GOP Application/Revision Application: Submitted or Under APD Review |
| ☐ SOP Application Review Application: Submitted or Under APD Review | ☒ N/A | |

| |
|---|
| **III. Fee Information** |
| **Check/Money Order/Transaction Number:** TBD |
| **Company name on Check:** APEX Bethel Energy Center, LLC |
| Fee Amount: $900.00 |

**Texas Commission on Environmental Quality**
**Registrations for Air Standard Permit**
**PI-1S**
**(Page 3)**

| | | |
|---|---|---|
| **IV.** | **Public Notice *(If* Applicable*)*** ***(public notice is not a requirement of the EGU Standard Permit)*** | |
| **A.** | Is the plant located at a site contiguous or adjacent to the public works project? | ☐ YES ☐ NO |
| **B.** | Name of Public Place: | |
| Physical Address: | | |
| City: | County: | |
| **C.** | Small Business Classification: | ☐ YES ☐ NO |
| **D.** | Concrete batch plants with enhanced controls, permanent rock crushers, and animal carcass incinerators shall place a copy of the technically complete application at the appropriate TCEQ regional office only. | |
| **E.** | Please furnish the names of the state legislators who represent the area where the facility site is located: | |
| State Senator: | | |
| State Representative: | | |
| **F.** | For Concrete Batch Plants, name of the County Judge for this facility site**:** | |
| County Judge: | | |
| Mailing Address: | | |
| City: | State: | ZIP Code: |
| **G.** | For Concrete Batch Plants, is the facility located in a municipality and/or extraterritorial jurisdiction of a municipality? | ☐ YES ☐ NO |
| If "YES," list the name(s) of the Presiding Officer(s) for the municipality and/or extraterritorial jurisdiction: | | |
| | | |
| Title: | | |
| Mailing Address: | | |
| City: | State: | ZIP Code: |
| **V.** | **Technical Information Including State and Federal Regulatory Requirements** ***Registrants must be in compliance with all applicable state and federal regulations and standards to claim a Standard Permit.*** | |
| **A.** | Is confidential information submitted and properly marked with this registration? | ☐ YES ☒ NO |
| **B.** | Is a process flow diagram and a process description attached? | ☒ YES ☐ NO |
| **C.** | Is a plot plan attached? | ☒ YES ☐ NO |
| **D.** | Are emissions data and calculations for this claim attached? | ☒ YES ☐ NO |
| **E.** | Is information attached showing how the general requirements and applicability (30 TAC § 116.610 and 116.615) are met? | ☒ YES ☐ NO |
| **F.** | Is information attached showing how the specific requirements are met? | ☒ YES ☐ NO |

Texas Commission on Environmental Quality
Form PI-1S
General Application for Air Permit Renewals
(Page 4)

| **VI. Signature Requirements** |
| --- |
| The signature below indicates that I have knowledge of the facts herein set forth and that the same are true and correct to the best of my knowledge and belief. I further state that to the best of my knowledge and belief, the project for which application is made will not in any way violate any provision of the Texas Water Code (TWC), Chapter 7, Texas Clean Air Act (TCAA), as amended, or any of the air quality rules and regulations of the Texas Commission on Environmental Quality or any local governmental ordinance or resolution enacted pursuant to the TCAA. I further state that I have read and understand TWC §§ 7.177 7.183, which defines ***Criminal Offenses*** for certain violations, including intentionally or knowingly making or causing to be made false material statements or representations in this application, and TWC §§ 7.187, pertaining to ***Criminal Penalties***. |
| Name: Stephen Naeve<br>*Print Full Name* |
| Signature: Stephen W. Naeve<br>*Original Signature Required* |
| Date: 06/19/12 |

# TABLE 1F
# AIR QUALITY APPLICATION SUPPLEMENT

| | |
|---|---|
| Permit No.: TBD | Application Submittal Date: |
| Company: APEX Bethel Energy Center, LLC | |
| RN: TBD | Facility Location: Intersection of County Rd. 2504 & F.M. 2706; Latitude: 31.887725 N, Longitude: -95.913241 W |
| City: Tennessee Colony | County: Anderson |
| Permit Unit I.D.: | Permit Name: GHG PSD Permit |
| Permit Activity: ☒ New Source ☐ Modification | |
| Project or Process Description: Compressed Air Energy Storage Facility | |

| Complete for all Pollutants with a Project Emission Increase. | POLLUTANTS | | | | | | |
|---|---|---|---|---|---|---|---|
| | Ozone | | CO | $PM_{10}$ | $PM_{2.5}$ | $SO_2$ | Other[1] (CO2e) |
| | VOC | $NO_X$ | | | | | |
| Nonattainment? (yes or no) | NO | NO | NO | NO | NO | NO | NO |
| Existing site PTE (tpy)? | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Proposed project emission increases (tpy from 2F)[3] | 7.9 | 39.9 | 47.0 | 9.6 | 8.5 | 3.7 | 459,125 |
| Is the existing site a major source? [2]If not, is the project a major source by itself? (yes or no) | NO | NO | NO | NO | NO | NO | YES |
| If site is major, is project increase significant? | NO | NO | NO | NO | NO | NO | YES |
| If netting required, estimated start of construction? | Grass roots facility - netting is not required. | | | | | | |
| Five years prior to start of construction | Grass roots facility - netting is not required. | | | | | | |
| Estimated start of operation | Grass roots facility - netting is not required. | | | | | | |
| Net contemporaneous change, including proposed project, from Table 3F. (tpy) | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| FNSR APPLICABLE? (yes or no) | NO | NO | NO | NO | NO | NO | YES |

1 Other PSD pollutants.
2 Nonattainment major source is defined in Table 1 in 30 TAC 116.12(11) by pollutant and county. PSD thresholds are found in 40 CFR § 51.166(b)(1).
3 Sum of proposed emissions minus baseline emissions, increases only. Nonattainment thresholds are found in Table 1 in 30 TAC 116.12(11) and PSD thresholds in 40 CFR § 51.166(b)(23).

The representations made above and on the accompanying tables are true and correct to the best of my knowledge.

| Stephen W. Naeve | Chief Operating Officer | 06/19/12 |
|---|---|---|
| Signature | Title | Date |

TCEQ

# TABLE 2F
# PROJECT EMISSION INCREASE

| | |
|---|---|
| **Pollutant[(1)]:** GHG (CO2e) | **Permit:** TBD |
| **Baseline Period:** N/A **to** N/A | |

| Affected or Modified Facilities[(2)] | FIN | EPN | Permit No. | Actual Emissions[(3)] | A<br>Baseline Emissions[(4)] | B<br>Proposed Emissions [(5)] | Projected Actual Emissions | Difference (B-A)[(6)] | Correction[(7)] | Project Increase[(8)] |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | TURBTRNA | TURBASTK | TBD | 0 | 0 | 222.770 | | 222.770 | | 222.770 |
| 2 | TURBTRNB | TURBBSTK | TBD | 0 | 0 | 222.770 | | 222.770 | | 222.770 |
| 3 | GENENG1 | GENENG1 | TBD | 0 | 0 | 23 | | 23 | | 23 |
| 4 | TURBSUA | TURBASTK | TBD | 0 | 0 | 6,389 | | 6,389 | | 6,389 |
| 5 | TURBSUB | TURBBSTK | TBD | 0 | 0 | 6,389 | | 6,389 | | 6,389 |
| 6 | TURBSDA | TURBASTK | TBD | 0 | 0 | 225 | | 225 | | 225 |
| 7 | TURBSDB | TURBBSTK | TBD | 0 | 0 | 225 | | 225 | | 225 |
| 8 | FUG1 | FUG1 | TBD | 0 | 0 | 248 | | 248 | | 248 |
| 9 | MAINT1 | MAINT1 | TBD | 0 | 0 | 85 | | 85 | | 85 |
| 10 | | | | | | | | | | |
| 11 | | | | | | | | | | |
| 12 | | | | | | | | | | |
| 13 | | | | | | | | | | |
| 14 | | | | | | | | | | |
| 15 | | | | | | | | | | |
| | | | | | | | | **Page Subtotal[(9)]** | | 459,125 |