January 17, 2014

Mr. Thomas H. Diggs
Associate Director
United States Environmental Protection Agency, Region 6
Air Programs Branch
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

Re: Response to Application Completeness Determination for FGE Power, LLC
Greenhouse Gas Prevention of Significant Deterioration Permit
FGE Texas Project: Westbrook, Mitchell County, Texas

Dear Mr. Diggs,

This letter is in response to your December 23, 2013 letter requesting additional information to complete the review of the initial Greenhouse Gas (GHG) Prevention of Significant Deterioration (PSD) permit application for the FGE Texas Project located in Westbrook, Mitchell County, Texas.

Please find attached our responses to the comments provided. The overall submittal is considered to contain confidential business information (CBI) and FGE Power is asserting confidentially with this submittal. FGE Power has prepared this response to comment that does not contain such CBI. The documents that contain CBI will be submitted under separate cover. If you have any questions or concerns with the information provided, please contact Brad Sohm with SWCA at (602) 274-3831 or bsohm@swca.com or myself at (281) 362-2830 or efarrell@fgepower.com.

Sincerely,

Emerson G. Farrell
CEO & President

Enclosure

Cc: Scott Deatherage, Gardere Wynne Sewell LLP
Brad Sohm, SWCA Environmental Consultants
Bill Jamieson, SWCA Environmental Consultants

(Public Version)

FGE Power's Responses to Mr. Thomas Diggs's Letter dated December 23, 2013

This correspondence has been prepared in response to your December 23, 2013 letter requesting additional information to complete the review of the initial Greenhouse Gas (GHG) Prevention of Significant Deterioration (PSD) permit application for the FGE Texas Project located in Westbrook, Mitchell County, Texas. The original comment and FGE Power's response are provided below.

EPA Comment:

On page 1 of the permit application, it is stated that the FGE power plant will be designed to achieve 55% efficiency. On page 60 of the application it is stated that according to Alstom, the GT-24 combustion turbines operating in combined cycle configuration and under optimal conditions have a base load efficiency of up to 60% (HHV). On page 33 of the permit application, it is stated that for the purposes of this application "normal" operation is considered to be 50% to 100% base load for the operating load range. Please clarify what will be the design efficiency of the FGE power plant. Also, please provide supplemental information that includes production output, gross heat rate and percent efficiency for the proposed combustion turbines (this information may be represented graphically in load/efficiency curves).

FGE Response:

FGE has confirmed that for the purposes of this application "normal" operation is considered to be 50% to 100% base load for the operating load range. The combustion turbine vendor (Alstom Power) has confirmed that during normal operation the FGE Texas Project will be designed to achieve a design efficiency ranging from 50.3% (heat rate of 6,790Btu/kWh [HHV]) to 53.4% (heat rate of 6,395 Btu/kWh [HHV]) at 95°F and 20% relative humidity. Alstom has also confirmed that under optimal conditions the GT24 combustion turbines operating in combined cycle configuration have a base load efficiency of up to 60% HHV. [1] Alstom has clarified that optimum performance is calculated with 100% methane (LHV) at ISO conditions, 45 mbar / 1.3 inHg condenser pressure.

As requested, FGE has provided the requested supplemental information (e.g. production output, gross het rate, and percent efficiency) at 95°F and 20% relative humidity along with a Load vs. Efficiency Curve for the proposed combustion turbines as Attachment 1. In addition, please refer to the revised Estimated Performance and Emissions Data dated June 20, 2013, provided as Attachment 2 for additional details. Please note this information has been submitted as Confidential Business Information (CBI).

[1] Obtained from Alstom's "Technical Performance – The Next Generation GT24", available at: http://www.alstom.com/Global/Power/Resources/Documents/Brochures/next-generation-gt24-gas-turbine-performance.pdf. Accessed October 2012. Note: Gas turbine performance calculated with 100% methane (lower heating value) ISO conditions.

EPA Comment:

2. **On page 5 of the permit application, it is stated that according to Alstom, the next generation GT24 turbines are capable of delivering more than 55% efficiency (heat rate of 5690 Btu/kWh) while operating in combined cycle mode. This is comparable to other similar classes of natural gas-fired combined cycle combustion turbines in the market. Also, on page 60 of the permit application, the proposed BACT is the efficient turbine design, but the analysis does not appear to compare the selected turbine model to other combustion turbines for which permits have been previously issued. Since efficient turbine designs can vary among turbines, please provide supplemental data to the BACT analysis that explains if other turbines were evaluated for this project and why they were eliminated? Please provide any specific details that outline different design configurations such as a combination of engines and turbines or one large unit as opposed to several smaller units that might have been evaluated to determine the most efficient operation for the proposed project.**

FGE Response:

The design heat rate for the combined cycle equipment being considered for the FGE Texas Project are specific to: (1) the gas turbine model, heat recovery steam generator size and design, the duct burner size, and the steam turbine design being considered for the project; (2) the specific pollution control equipment specified for the project including selected catalytic reduction and oxidation catalyst and (3) specific atmospheric conditions at the FGE Texas Project site including ambient temperature and relative humidity (summer condition of 95°F/20% RH and winter condition of 5°F /55% RH).

The most efficient way to generate electricity from a natural gas fuel source is the use of a combined cycle design, as this configuration recovers additional thermal energy, otherwise wasted in a simple cycle plant, to create additional electrical power and ultimately increase the plant's energy efficiency. The EPA guidance document states, "combined-cycle CTs, which generally have higher efficiencies than simple-cycle turbines, should be listed as options when an applicant proposes to construct a natural gas-fired facility." [2]

The business purpose of the FGE Texas Project is to generate approximately 1,600 MWs of power that may be dispatched to Northern or Western Texas. The project will contribute to the power needed to address the shortage and reliability issues facing the Texas electrical grid managed by the Electric Reliability Council of Texas (ERCOT). Studies and analysis conducted by or on behalf of ERCOT, the Public Utility Commission of Texas (PUC), and the North American Electric Reliability Corporation have concluded that the margins of electrical production necessary to meet peak demand are or soon will be insufficient. The results could include rolling brownouts or blackouts at certain times and in certain areas of the state. Construction of new electricity generation capacity is critical for the state. The FGE Texas Project provides a significant contribution to new generation.

To accomplish this goal, FGE proposed to install four Alstom GT24 combined cycle combustion turbines (CCCT) at the FGE Texas I Project in order to supply power during high demand. The Alstom technology will allow for proposed facility to operate with the highest base and part load efficiency, and unprecedented low-load efficiency. As clarified above, according to Alstom, the

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[2] U.S. EPA, Office of Air Quality Planning and Standards, PSD and Title V Permitting Guidance for Greenhouse Gases. March 2011. Available at: www.epa.gov/nsr/ghgdocs/ghgpermttingguidance.pdf.

next generation GT24 turbines are capable of delivering more than 60% efficiency (heat rate of 5,690 Btu/kWh) while operated in combined cycle mode.[3] Alstom has clarified that optimum performance is calculated with 100% methane (LHV) at ISO conditions, 45 mbar / 1.3 inHg condenser pressure. Other similar classes of natural gas-fired combined cycle combustion turbines specify heat rates ranging from 5,960 to 6,090 Btu/kWh.[4, 5]

The Alstom turbines are unique in that the turbines can be operated in a current BACT compliant Low Load Operating (LLO) mode ("parking feature"). Using sequential combustion technology, the LLO is achieved by turning the second combustor off, while the first combustor maintains operation at its optimal point allowing the full combined cycle power block to be parked at a significantly reduced minimum load point (approximately 8 to 10 percent of unfired maximum load). Because the first combustor maintains operation at its optimal point, each power block while operating in the parking feature will maintain compliance with greater than 50 percent to base load emission concentrations. In addition, the parking feature is uniquely configured to allow the power block to provide more than 450 MW to the grid in approximately 10 minutes without risk of start failure or excessive wear. [6]

The Alstom technology was selected in part for its very broad operating range, thus optimizing the potential to provide critical grid support and ancillary services to the ERCOT marketplace, as well as having heat rate profiles which are approximately 6% to 7% more efficient than competing technology options. Additionally, FGE has secured power block pricing that is substantially below the values requested by competing technology providers. This operating flexibility and efficiency will provide significant benefits to the ERCOT grid when integrating the roughly 10,000 MW of intermittent wind energy resources located between their West Texas location and the load centers of the market, all of which are over 250 miles east of the predominate location of the wind energy projects.

FGE also conducted a review of recently issued PSD permit and permit applications for GHG emissions from power plants utilizing combined-cycle natural gas turbines. Each of these permits identified inherently lower-emitting processes, practices, and designs discussed below that could be used to establish BACT for the combined-cycle natural gas turbines proposed by FGE. The turbine efficiency designated as BACT on both a pollutant emissions basis (CO_2/MWh) and an energy efficient basis (Btu/kWh). A detailed listing of recently issued GHG permits and applications under review for GHG emissions from combustion turbines is provided as Attachment 3.

As detailed in Attachment 3, recent permits have been issued for a handful of combined cycle units. A summary comparison of the recently permitted combined cycle combustion turbine units is presented in Table 1 below.

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[3] Obtained from Alstom's "Technical Performance – The Next Generation GT24", available at: http://www.alstom.com/Global/Power/Resources/Documents/Brochures/next-generation-gt24-gas-turbine-performance.pdf. Accessed October 2012. Note: Gas turbine performance calculated with 100% methane (lower heating value) ISO conditions.

[4] Obtained from GE Energy's "Heavy duty gas turbine products:, available at: http://www.ge-energy.com/content/multimedia/_files/downloads/dataform_2046207337_2809806.pdf. Accessed November 28, 2012.

[5] Obtained from Siemen's "Siemens Gas Turbine SGT6-5000F Application Overview", available at: http://www.energy.siemens.com/us/pool/hq/power-generation/gas-turbines/downloads/SGT6-5000F.pdf. Accessed November 28, 2012.

[6] Obtained from Alstom's "Technical Performance – The Next Generation GT24", available at: http://www.alstom.com/Global/Power/Resources/Documents/Brochures/next-generation-gt24-gas-turbine-performance.pdf. Accessed October 2012).

Table 1. Summary of Recently Permitted Combined Cycle Combustion Turbine Units

Make	Model	Combined Cycle		
		ISO Rated Power (MW)	Gross Heat Rate (Btu/kWh)	lb CO_2/MWh
GE Energy	7FA [1]	183 - 195	7,319 - 7,861.8	920 - 934.5
GE	7EA [2]	80 - 87	8,334	-
Siemens	FD2/FD3 [3]	168 - 180	7,730	920
Siemens	SGT6-5000F [4]	265 - 271	7,649	909.2 – 912.7

[1] Cricket Valley Energy Center, Dover, NY; La Paloma Energy Center, Harlingen, TX; Palmdale Hybrid Power Plant, Palmdale, CA; and Lower Colorado River Authority, Thomas C. Ferguson Power Plant, Horseshoe Bay, TX
[2] Air Liquide Large Industries, Bayou Cogeneration Plant, Pasadena, TX; Freeport LNG Development, Freeport, TX
[3] Calpine Corporation, Channel Energy Center, Otay Mesa, CA
[4] La Paloma Energy Center, Harlingen, TX

For comparison purposes, the proposed heat rate for the Alstom GT24 turbines without duct firing is 7,625 Btu/kWh (HHV, gross) and with duct firing is 7,567 Btu/kWh (HHV, gross). The proposed emission rate on a pound CO_2/MWh (net) basis without duct firing is 832 and 889 with duct firing. Therefore, the FGE Texas project when compared to recently permitted combined cycle combustion units of similar size represents BACT.

EPA Comment:

3. **On page 33 of the permit application, it is stated that each power block (consisting of two combustion turbines and a single steam turbine generator) will generate approximately 728 MW (gross) of power at an ambient temperature of 5°F and 55% relative humidity during combined cycle operation (up to 810 MW gross power at 5°F and 55% relative humidity). It appears as though two different design power ratings are given for the proposed power block (i.e., two combustion turbines and a single steam turbine) at the same conditions. Please clarify.**

FGE Response:

The combustion turbine vendor (Alstom Power) has confirmed that during winter conditions each power block (consisting of two combustion turbines and a single steam turbine generator) will generate approximately 714 MW (gross) of power at an ambient temperature of 5°F and 55% relative humidity during combined cycle operation without duct firing (up to 810 MW gross power at 5°F and 55% relative humidity with duct firing). During summer conditions each power block (consisting of two combustion turbines and a single steam turbine generator) will generate approximately 624 MW (gross) of power at an ambient temperature of 95°F and 20% relative humidity during combined cycle operation without duct firing (up to 728 MW gross power at 95°F and 20% relative humidity with duct firing).

Please refer to the revised Estimated Performance and Emissions Data dated June 20, 2013, provided as Attachment 2 for additional details. Please note this table has been submitted as Confidential Business Information (CBI).

EPA Comment:

4. **Beginning on page 35 of the permit application, a list and brief summary is provided for the other equipment (i.e., condenser cooling tower, four diesel storage tanks, lube oil**

reservoirs and ammonia storage and unloading) proposed for the project. Although it is stated that this equipment is not a GHG emission source, it should be represented on the process flow diagram to depict what the project will entail to for a complete permit record. In addition to identifying the emission source with the associated EPN, please label as a non-GHG source for clarity. Also, please show on the process flow diagram the emission sources for fugitives (CH4, CO2, and SF6, fire pump engine, emergency electrical generator engine.)

FGE Response:

Revised process flow diagrams, which include all proposed equipment, including fugitive emission sources, associated with the FGE Texas Project are provided as Attachment 4.

EPA Comment:

5. **On page 70 of the permit application, it is stated that the design base load net heat rate for the Alstom GT24 combustion turbines is 6408 Btu/kWh (HHV, gross) without duct firing. The following margins were used to adjust the design base load heat rate the proposed combustion turbine being considered for this project: 3.3% design margin, 6.0% performance margin, 3.0% degradation margin, and 2.0% conversion of gross output to net. Please provide a basis and supplemental manufacturer's documentation to substantiate these assertions.**

FGE Response:

As requested FGE has provided the following as a basis and supplemental manufacturer's documentation to substantiate the margins used to adjust the design base load heat rate.

Design Margin - Typically the market for contracting the engineering and construction of combined cycle power plants has a design margin of 5% for the guaranteed net MW output and net heat rate. This is the condition for which the contractor has a "make right" obligation to continue tuning the facility's performance to achieve this minimum value. Therefore, the contractor must deliver a facility that is capable of generating 95% of the guaranteed MW and must have a heat rate that is no more than 105% of the guaranteed heat rate. Given FGE's confidence surrounding the expertise and experience of combined cycle power plant construction, FGE has elected to reduce the 5% design margin to 3.3%. The effects of the design margin guarantee must be accounted for and other applicants have utilized similar 3.3% design margin; reference the La Paloma Energy Center in Cameron County, Texas.

Performance Margin on Combustion Turbine and Steam Turbine Generators - The performance margin for equipment degradation relates to the combustion turbine and steam turbine generators. According to Figure 24 of the California Energy Commission publication CEC-200-2010-002; Cost of Generation Model Users Guide Version 2 dated March of 2010, the "sawtooth curve" indicates that the degradation will be limited to 2% between inspections and that 75% of that performance will be recovered resulting in a 20 year degradation of 4.5%. According to the combustion turbine vendor (Alstom Power), typically, performance degradation during the first 36,000 hours (the normally recommended interval for inspection and maintenance) is 2.01% (heat rate degradation) to 2.64% (power output degradation). Alstom has also indicated that depending on the equivalent operating hours (EOH), approximately 28% to a 44% of that performance will be recovered; and would result in a 20 year degradation of approximately 2.23% and a 25 year degradation of approximately 2.32%.

However, considering the atmospheric conditions at the project location (e.g., high ambient temperature, humidity, and ~2,200 foot elevation, etc.); FGE has taken a slightly more conservative view of this degradation. FGE projects the potential degradation to be 3.5% between the 36,000 EOH inspections (considerably less than the potential 4.5% stated in the CEC publication) and assuming a 44% performance recovery; calculating a 20 year degradation of 6%. The effects of the performance margin must be accounted for and other applicants have utilized similar 6% design margin; reference the La Paloma Energy Center in Cameron County, Texas.

As requested, FGE has provided the requested manufacturer's documentation with regards to the Reachable Degradation of Power Output and Heat Rate of a Typical Alstom GT24 Power Train as Attachment 5. Please note this information has been submitted as Confidential Business Information (CBI).

Degradation Margin for the Auxiliary Plant Equipment - The degradation margin for the auxiliary plant equipment also encompasses the heat recovery steam generators (HRSG's). This accounts for the scaling and corrosion of the boiler tubes over time as well as minor potential fouling of the heating surface of the tubes. Similar to the HRSG's, scaling and corrosion of the condenser tubes will also degrade the heat transfer characteristics and thus the performance of the steam turbine generator. Given the combustion turbine degradation accounts for the majority of the performance loss and as well as the large variation in operating parameters (fuels, temperatures, water treatment, cycling conditions, etc.), little operating data has been gathered and published that illustrate a clear performance degradation characteristic. However, the effects of the degradation must be accounted for and other applicants have utilized similar 3% degradation margins for the auxiliary plant equipment; reference the La Paloma Energy Center in Cameron County, Texas, LCRA Ferguson CCPP in Marble Falls, Texas and the Russell City Energy Center in Hayward, California.

It is our understanding that EPA has requested the proposed heat rate limit for the permit needs to be on a gross basis. Therefore, the 2.0% adjustment for the conversion of gross output to net has not been applied and the heat-input efficiency limit has been recalculated. Please refer to FGE's response to EPA Comment 6 for further details.

EPA Comment:

6. **On page 75 of the permit application, Table 10 includes a summary of the proposed BACT limits for the GHG emission sources for this project. The proposed BACT limit for the combustion turbine is 832 lb CO_2/MWh (net, without duct firing) and 7325 BTU/kWh (net, without duct firing). Please provide the proposed BACT limit in gross values. Also, throughout the permit application it is indicated that duct burners will be utilized; however, the proposed BACT limit presented in Table 10 for the combustion turbines only appears to propose a BACT limit without duct firing. Please provide supplemental information that explains why an additional BACT limit was not proposed for the combustion turbines when in duct firing operating mode. Please provide the supporting calculations for the proposed BACT output-based limits for the combustion turbine and the basis to support the rationale used to derive the limit.**

FGE Response:

It is our understanding that EPA has requested the proposed heat rate limit for the permit needs to be on a gross basis. Therefore, the 2.0% adjustment for the conversion of gross output to net has not been applied and the heat-input efficiency limit has been recalculated as the proposed heat rate for the Alstom GT24 turbines without duct firing is 7,625 Btu/kWh (HHV, gross) and with duct firing is 7,567 Btu/kWh (HHV, gross). The proposed emission rate on a pound CO_2/MWh (net) basis without duct firing is 832 and 889 with duct firing. Updated emission calculations, which include the proposed BACT output-based limits for the combustion turbines are provided as Attachment 6.

As discussed in Response 2, the FGE Texas project when compared to recently permitted combined cycle combustion units of similar size represents BACT.

EPA Comment:

7. **The application indicates a proposal for 365 startup and 365 shutdown events for each turbine. Please provide supplemental data to support the rationale for this number of proposed startups and shutdowns. The discussion should include a detailed explanation of the power plant's anticipated operating mode that justifies the proposed startup and shutdown events used to calculate the emission limits.**

FGE Response:

FGE Texas cannot project with clarity the future dispatch of the facility due to the uncertainties of, among other things, climate and weather patterns, the level of additional of future generation construction, required operating reserve margins, population and load growth, and fuel pricing. Additionally, it is ultimately the grid operator's decision to dispatch generation to best serve the demand and ensure the stability of the system. It is for this reason that FGE must anticipate the facility could be called to operate at reduced loads and has prepared an application that reflects this potential operating profile. However, the Project has also performed further research into the potential dispatch of the facility and with the support of third party experts FGE Texas believes the following items could support a dispatch level above the filing estimate:

1. The Alstom KA-24 platform (Configuration includes two GT24 gas turbines, two heat recovery steam generators (HRSG) and one steam turbine) operates at an efficiency level superior to other natural gas fired CCGT facilities within the ERCOT marketplace. This factor, along with competitive start costs and operating cost structure ultimately secured by FGE Texas during the development phase, should result in a superior position within the ERCOT economic dispatch stack in the future;
2. The project's strategically located point of interconnection with the ERCOT grid provides direct access to the robust economic growth ongoing in the historical ERCOT North and West operating zones; and
3. During the development phase, FGE Texas has confirmed that ERCOT grid access can be secured without meaningful upgrades to the transmission system. Additionally, while no definitive conclusion can be reached, it would appear that minimal transmission constraints will encumber the unit's dispatch for the foreseeable future. As such the unit should perform well within the energy-only marketplace with a favorable nodal market basis differential.

Based on these studies, FGE anticipates that the new facility will have a sufficient capacity at a high enough efficiency that ERCOT will dispatch its generation as base load.

FGE has estimated emission assuming the combustion turbines could have a single SUSD event per day a maximum of 365 startup events and 365 shutdown events per turbine annually. Each MSS event is expected to not exceed 210 (includes cold startup and shutdown) minutes during combined cycle operations (180 minutes for a cold startup, 151 minutes for a warm startup, 56 minutes for a hot startup, and 30 minutes for a shutdown). Therefore, the FGE Texas project expects the maximum number of SUSD hours to range between 523 (assumes all hot starts) to 1,277 (assumes all cold starts) annually, depending on how the units will be dispatched.

According the to the combustion turbine vendor (Alstom Power), the maximum fuel heat input during a start-up event is 820 MMBtu/hr (HHV). This is the total heat input (HHV basis) required during a hot start and represents the maximum (i.e., worst-case) fuel heat input from ignition to compliance. Therefore, FGE proposes the following for start-up and shutdown emissions and heat input limitations listed in Table 2. Please refer to Attachment 6 for further details.

Table 2. Proposed Start-up and Shutdown Emissions and Heat Input Limitations (per Turbine)

Turbine Model	BACT Emission Limit (tons CO_2/hr)	Annual Emission Limit (tons CO_2e/yr)	Maximum Heat Input (MMBtu/hr)
Alstom GT24	48.0	36,506	820.0

Furthermore, estimated emissions and the proposed emission limits are based on turbine performance for the maximum hourly emission rates. The maximum tpy emissions have been proposed as the worst-case normal operations at 8,760 hr/yr. These tpy emission limits are being proposed as the basis for the maximum allowable listed within the permit. Thus, the project will be authorized to operate under normal conditions 8,760 hr/yr. FGE did not "double count" startup and shutdown emissions in this proposed limit.

EPA Comment:

8. Please provide the following additional technical and economic details for this project and its potential for installing a CCS system for recovering CO2 for both enhanced oil recovery (EOR) and non-EOR geologic sequestration:

- **a. An itemized cost estimate for capture technology (amine units, cryogenic units, dehydration units and compression facilities) and transport (pipeline, compression) for capture technology that is mentioned on page 66 of the permit application.**
- **b. Adverse environmental impact(s)/air emission estimates associated with CCS scenarios for both non-GHGs and GHGs.**
- **c. Water utilization increases and any associated issues that should be considered for the specific site/location such as water availability.**
- **d. Please show and justify any capital cost recovery factors for the project and why appropriate for the project/company.**

FGE Response:

a. FGE has provided the following additional technical and economic details for the FGE Texas Project and its potential for installing a CCS system for recovering CO_2 for both EOR and non-EOR geologic sequestration. These updated costs are provided in Attachment 7. Please note this information has been submitted as Confidential Business Information (CBI).

The total estimated capital cost for CCS is $1,503 million, which is greater than 35% total capital cost of the proposed project. The total estimated capital cost includes the capital cost for pipeline to convey the CO_2 estimated to be $83 million for a 100 mile long 10-inch diameter pipeline.

Including the costs of capture and long-term geologic storage (non-EOR), FGE estimates an annualized cost of $312 million ($119/ton of CO_2); while the cost of capture and EOR has been estimated at $271 million ($103/ton of CO_2) assuming the captured and compressed CO_2 could be sold for $10/ton.

While the IRS has provided tax credit for two types of CO_2 sequestration (a $20/ton credit for CO_2 sequestered in geologic storage and $10/ton credit for "tertiary injectant in a qualified EOR or natural gas recovery project") the credit is capped and ceases to be available once credits have been claimed for sequestering 75,000,000 tons of CO_2. As of May 2013, credits have already been claimed for the sequestration of 20,858,926 tons of CO_2. Thus, FGE believes the 75,000,000 credits would be consumed by the end of 2018 and the project would only be able to claim credits for operating years 2016-2018.

Additionally, FGE has confirmed that the cost of CapEx is ~$1,000/kW for the Alstom package and the plant's net heat rate would increase by 25%. For example we are at 7,000 Btu/kWh, then it would now be at 8,750 Btu/kWh. Thus, making it a highly inefficient power generation source even when compared to older legacy plants.

Moreover, FGE is currently not aware of a significant market for the sale of CO_2, and in the future if CCS is implemented the market will become saturated, further depressing the value. Therefore, it is FGE opinion that EOR in the region would have no economic value. Further, it is beyond the scope of the business purpose for this project to become contractually obligated to provide CO_2 for commercial purposes, including EOR.

Based on the normalized control cost and comparison of total capital cost of control to project cost, FGE maintains that CCS is not economically feasible.

b. FGE has provided the following information to describe the potential adverse environmental impact(s)/air emission estimates associated with CCS scenarios for both non-GHGs and GHGs.

As discussed in the City of Austin's Austin Energy Prevention of Significant Deterioration Greenhouse Gas Permit Application, Sand Hill Energy Center, Del Valle, Travis County, Texas, September 2013, potential environmental impacts resulting from CO_2 injection that still require assessment are significant unknown risks before CCS technology can be considered feasible include:

- Uncertainty concerning the significance of dissolution of CO_2 into brine;
- Risks of brine displacement resulting from large-scale CO_2 injection, including a pressure leakage risk for brine seeping into underground drinking water sources and/or surface water;

- Risks to fresh water as a result of leakage of CO_2, including the possibility for damage to the biosphere, underground drinking water sources, and/or surface water
- Potential effects on wildlife; and
- Risk of metals leaking from underground formations as a result of the injection of acid gases.

While implementation of CCS would reduce the amount of CO_2 emitted by the facility, the facility net power output would be decreased due to the additional power requirements for CCS. Therefore, the facility would generate less electricity for sale for the same amount of fuel input without CCS. The DOE NETL study has quantified the reduction in net power from a combined cycle natural gas facility from the implementation of CCS in Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous and Natural Gas to Electricity, DOE/2010/1397 (Revision 2a, September 2013). The DOE NETL study quantified an approximately 15% reduction in net power output from implementation of CCS.

Therefore, for the purposes of this analysis, it is assumed that criteria pollutants and HAPs would be increased by approximately 15% due to the combustion of additional fuel to produce the same net power requirements of the facility without CCS. Pollutant emissions without CCS, with the use of CCS, and the increase or decrease that would result from the implementation of CCS for criteria pollutants, HAPs, and GHGs is presented in the table below under the maximum operational scenario (i.e., four combustion turbines arranged in a 2-on-1 configuration).

Pollutant	Without CCS (tpy)	With CCS (tpy)	*Emissions Increase or Decrease (+/-) from CCS Implementation (tpy)*
NO_X	350	403	*53*
$PM/PM_{10}/PM_{2.5}$	287	330	*43*
SO_X	37	42	*6*
VOC	297	342	*45*
HCHO	5	6	*1*
CO_2	5,838,873	671,470	*(5,167,402)*
CH_4	1,893	2,177	*284*
N_2O	10	12	*2*
CO_2e	5,889,292	729,453	*(5,159,840)*

Furthermore, additional emissions would be generated due to the fuel-fired equipment and/or generation of electricity to power the compressors to transport the captured CO_2 for both EOR and non-EOR activities.

c. The initial air quality New Source Review (NSR) application submitted in May 2013 to the Texas Commission on Environmental Quality (TCEQ) included two (2) cooling towers (one for each proposed power block). The cooling tower design in the permit application proposed the use of wet-cooling towers equipped with twelve (12) cells per unit and a water circulation rate of 140,000 gallons per minute (gpm) on a per tower basis. Total dissolved solids (TDS) content for the cooling tower water was estimated in the permit application at a rate of 21,000 parts per million (ppm). High-efficiency drift eliminators were proposed that would provide a minimum drift elimination rate of 0.0005% drift to control particulate matter.

Since the application submittal, the proposed cooling tower design has been revised. Instead of using wet-cooling towers, FGE is now proposing the use of a hybrid design combining air-cooling and water-cooling. The proposed modification would change the number of wet-cooling tower cells per cooling tower from the twelve (12) proposed in the original application to five (5) cells in the new, proposed hybrid design and would reduce water usage from 140,000 gpm to 106,000 gpm per cooling tower. Estimated TDS content of 21,000 ppm and the use of drift eliminators with drift elimination rates of 0.0005% drift would not change. The remaining heat balance would be handled with the use of a 20-cell air cooled condenser (ACC) unit per power block. The AACs are completely closed units and therefore would have no potential to emit. This new cooling tower design has been proposed to take advantage of the latest advances in the state-of-the-science of cooling tower technology and to reduce project water usage.

However, the implementation of CCS would significantly increase the cooling water requirements of the facility, necessitating the consumption of more water. Using the same general methodology as presented in the DOE NETL guidance document (September 2013), the implementation of CCS alone would result in the following additional water consumption:

CCS Water Usage Type	CCS Water Usage (gpm)
Raw Water Withdrawal	6,515,034
Process Water Discharge	1,747,936
Raw Water Consumption	4,767,098

Raw water withdrawal represents the rate at which water would be withdrawn from ground water sources or diverted from other water sources. Process water discharge is the water that is discharged back into water supplies. The raw water consumption, then, is the difference between the water withdrawn and the water discharged, and represents the water withdrawn that is "evaporated, transpired, incorporated into products or otherwise not returned" (DOE NETL September 2013). Based on the DOE NETL study, the implementation of CCS alone would consume almost 5 million more gallons of water per minute than the building of the facility without CCS.

d. FGE has used project specific equity to debt ratio, cost of equity, cost of debt data to estimate a specific capital cost recovery factor to estimate the annual cost of implementing CCS as presented in Attachment 7. The equity to debt ratio, cost of equity, cost of debt values presented by FGE are only a best guess, as they will not be known or certain until the actual day of the construction financing. Additionally, the cost of equity is difficult to estimate, as there is not a specific cost to the equity, as it is based on projected returns under a dozen different models with pre and post tax, levered considerations. In addition, the equipment life was assumed to be 25 years.

The effects of the capital recovery factor must be accounted for and other applicants have utilized similar methodology; reference the Air Liquide Large Industries Redevelopment of the Cogeneration Facility in Pasadena, Texas (PSD-TX-612-GHG) dated October 14, 2013. Please note this information has been submitted as Confidential Business Information (CBI).

EPA Comment:

9. **The global warming potentials (GWP) have been revised by EPA. The final rule published on November 29, 2013 in the Federal Register will be effective for all permits issued on or after January 1, 2014. The methane value was increased from 21 to 25 (times more potent than CO2), the N2O value was decreased from 310 to 298, and the N2O value was decreased from 23,900 to 22,800. Due to the prospective changes in the emissions for methane in the FGE Power application, please provide an updated emission tables using the new GWPs so that EPA can cross-check its own calculations.**

FGE Response:

Updated emission tables using the new GWPs published in the final rule on November 29, 2013 for the FGE Texas Project are provided as Attachment 6.

Attachments:

(1) Load vs. Efficiency Curve (CBI)
(2) Estimated Performance and Emissions Data dated June 20, 2013 (CBI)
(3) Recently Issued Permits and Applications Under Review for Greenhouse GHG Emissions from Combustion Turbines
(4) Revised Process Flow Diagrams
(5) Reachable Degradation of Power Output and Heat Rate of a Typical Alstom GT24 Power Train (CBI)
(6) Updated Emission Tables
(7) Updated CCS Cost Estimate (CBI)

Attachment 1 –
Load vs. Efficiency Curve (CBI)

THIS INFORMATION HAS BEEN REMOVED FROM THIS PUBLIC DOCUMENT AND SUBMITTED UNDER SEPARATE COVER IN WHICH THE APPLICANT ASSERTS THE MATERIAL AND INFORMATION IS CONFIDENTIAL BUSINESS INFORMATION.

Attachment 2 –
Estimated Performance and Emissions Data dated June 20, 2013 (CBI)

THIS INFORMATION HAS BEEN REMOVED FROM THIS PUBLIC DOCUMENT AND SUBMITTED UNDER SEPARATE COVER IN WHICH THE APPLICANT ASSERTS THE MATERIAL AND INFORMATION IS CONFIDENTIAL BUSINESS INFORMATION.

Attachment 3 –
Recently Issued Permits and Applications under Review for Greenhouse GHG Emission from Combustion Turbines

Table C-1. Recently Issued Permits and Applications Under Review for Greenhouse Gases Emissions from Combustion Turbines

No.	Permit Authority	Permit Number	Company Name Facility Name Location	# of Units	Unit Description Model	Capacity	Control Technology	Thermal Efficiency BTU (HHV) per kWh (gross)	PTE tpy CO2e	Proposed BACT Limits Parameter	Proposed BACT Limits Units	Monitoring
Recently Issued Permits												
1	USEPA R6	PSD-TX-1244-GHG (issued 9-28-2011)	Lower Colorado River Authority Thomas C. Ferguson Power Plant Horseshoe Bay, TX	2	GE 7FA	195 MW	Combined cycle operation Efficient design	N/A	909,833	908,958	tpy CO2	Fuel monitoring or CEMS
										16.80	tpy CH4	
										1.70	tpy N2O	
										0.46	ton CO2/MWh (net)	
										7,720	Btu/kWh (HHV)	
											[365 day rolling avg]	
2	USEPA R9	PSD-SE-09-01 (issued 10-18-2011)	Palmdale Hybrid Power Project Palmdale, California	2	GE 7FA (with a 50 MW solar thermal array field)	N/A	Combined cycle operation	7,319	N/A	7,319	Btu/kWh (HHV)	N/A
3	USEPA R1	(issued 4-12-2012)	Pioneer Valley energy Center Westfield, MA	1	Mitsubishi M501G	431 MW	Combined cycle operation	N/A	N/A	825	CO2e/MWh (initial source test)	N/A
										895	CO2e/MWh [365-day rolling avg]	N/A
4	USEPA R9	PSD-SD-11 (issued 11-19-2012)	Pio Pico Energy Center, LLC Pio Pico Energy Center Otay Mesa, CA	3	GE LMS100	100 MW 930 mmBtu/hr	Simple cycle operation Efficient design	N/A	N/A	1,181	lb CO2/MWh (net) Btu/kwH (HHV - gross)	Fuel monitoring CEMS, CMS
										9,196		
5	USEPA R6	PSD-TX-955-GHG (issued 11-29-2012)	Calpine Corporation Channel Energy Center Pasadena, Texas	1	Siemens FD2/FD3	168-180 MW	Combined cycle operation Efficient design Process monitoring	7,730	1,003,355	1,002,391	tpy CO2 [365-day rolling avg]	Fuel monitoring, CEMS
										18.55	tpy CH4 [365-day rolling avg]	
										1.86	tpy N2O [365-day rolling avg]	
										0.460	tons/MWh [30-day rolling avg]	
										7,730	Btu/kWh [30-day rolling avg]	
6	USEPA R6	PSD-TX-979-GHG (issued 11-29-2012)	Calpine Corporation Deer Park Energy Center Dallas, TX	1	Siemens FD2/FD3	168-180 MW	Combined cycle operation Efficient design Process monitoring	7,730	1,045,635	1,044,629	tpy CO2 [365-day rolling avg]	Fuel monitoring, CEMS
										19.34	tpy CH4 [365-day rolling avg]	
										1.93	tpy N2O [365-day rolling avg]	
										0.460	tons/MWh [30-day rolling avg]	
										7,730	Btu/kWh [30-day rolling avg]	
7	USEPA R6	PSD-TX-104949-GHG (issued 3-8-2013)	Copano Processing, LP Houston Central Gas Plant Sheridan, TX	2	Solar Mars 100	15,000 hp	Efficient design Waste heat recovery Process monitoring	N/A	65,097	1.32	ton CO2e/hp-hr	monitoring AFR monitoring Quarterly source test
8	USEPA R6	PSD-TX-110557-GHG (issued 10-17-2013)	DCP Midstream, LP Jefferson County NGL Fractionation Plant Jefferson County, TX	2	Solar Saturn T-4700	43 mmBtu/hr	Efficient design Waste heat recovery Process monitoring	N/A	24,610	24,610	tpy CO2e	None proposed

Table C-1. Recently Issued Permits and Applications Under Review for Greenhouse Gases Emissions from Combustion Turbines (Continued)

No.	Permit Authority	Permit Number	Company Name Facility Name Location	# of Units	Unit Description Model	Capacity	Control Technology	Thermal Efficiency	PTE	Proposed BACT Limits		Monitoring
								BTU (HHV) per kWh (gross)	tpy CO2e	Parameter	Units	
9	USEPA R6	PSD-TX-1288-GHG (issued 11-6-2013)	La Paloma Energy Center Harlingen, TX	2	GE F7FA	183 MW	Combined cycle operation Energy Efficiency, Practices and Designs	7,861.8	1,300,674	1,261,820	tpy CO2	Fuel monitoring or CEMS
										23.4	tpy CH4	
										2.40	tpy N2O	
										934.5	lb CO2/MWh	
										73	lb CO2/hr (startup)	
					Siemens SGT6-5000F(4)	265 MW		7,649	1,451,772	1,415,907	tpy CO2	
										26.27	tpy CH4	
										2.60	tpy N2O	
										909.2	lb CO2/MWh	
										97	lb CO2/hr (startup)	
					Siemens SGT6-5000F(5)	271 MW		7,679	1,642,317	1,594,162	tpy CO2	
										29.5	tpy CH4	
										3.00	tpy N2O	
										912.7	lb CO2/MWh	
										94	lb CO2/hr (startup)	
10	USEPA R6	PSD-TX-612-GHG (issued 11-21-2013)	Air Liquide Large Industries, Bayou Cogeneration Plant Pasadena, Texas	4	GE 7EA	80 MW	Good combustion practices, operation and maintenance Fuel selection	8,334	N/A	485,112	tpy CO2	365-day rolling average / CEMS
11	USEPA R2	(draft issued 5-25-2011)	Cricket Valley Energy Center Dover, NY	3	GE 7FA	N/A	Combined cycle operation	N/A	N/A	7,605	Btu/kwH (HHV – ISO w/o duct firing)	N/A
12	USEPA R6	PSD-TX-1290-GHG (draft issued 9-22-2013)	El Paso Electric Company Montana Power Station El Paso, TX	4	GE LMS100	100 MW	Simple Cycle Operation Efficient design Evaporative cooling Good operating practices Fuel selection	9,074	227,840	227,840	tpy CO2e [365-day rolling avg]	CEMS, Fuel quality monitoring
										1,194	lb CO2/MWh [30-day rolling avg]	
13	USEPA R6	PSD-TX-1302-GHG (draft issued 12-2013)	Freeport LNG Development Liquefaction Plant Freeport, TX	1	GE Frame 7EA	87 MW	Efficient design Waste heat recovery Evaporative cooling	N/A	562,693	562,141	tpy CO2	Fuel monitoring or CEMS
										0.03	tpy CH4	
										1.06	tpy N2O	
Applications Pending												
1	USEPA R6	N/A (submitted 5-25-2012)	DCP Midstream, LP Hardin County NGL Fractionation Plant Hardin County, TX	2	Solar Saturn T-4700	43 mmBtu/hr	Efficient design Waste heat recovery Process monitoring	N/A	24,610	24,610	tpy CO2e	None proposed
2	USEPA R6	N/A (submitted 6-20-2012)	Calhoun Port Authority ES Joslin Power Station Point Comfort, TX	3	GE 7FA	208 MW	Combined cycle operation Efficient design Evaporative cooling Steam turbine bypass	N/A	N/A	7,730	Btu/kWh (HHV)	N/A

Table C-1. Recently Issued Permits and Applications Under Review for Greenhouse Gases Emissions from Combustion Turbines (Continued)

No.	Permit Authority	Permit Number	Company Name Facility Name Location	# of Units	Unit Description Model	Capacity	Control Technology	Thermal Efficiency BTU (HHV) per kWh (gross)	PTE tpy CO_2e	Proposed BACT Limits Parameter	Proposed BACT Limits Units	Monitoring
3	USEPA R6	N/A (submitted 11-13-2012)	Guadalupe Power Partners LP Guadalupe Generating Station Marion, Texas	2	GE 7FA.03	383 – 454 MW	Simple cycle operation	10,673 – 11,456	511,429 – 681,839	511,429	tpy CO2e	
					GE 7FA.04					11,121	Btu/kWh	
					4GE 7FA.05					522,722	tpy CO2e	
					Siemens 5000F(5)					10,826	Btu/kWh	
										601,520	tpy CO2e	
										10,673	Btu/kWh	
										681,839	tpy CO2e	
										11,456	Btu/kWh	
4	USEPA R6	N/A (submitted 11-26-2012)	NRG Texas Power LLC Cedar Bayou Unit 5 Baytown, Texas	2	GE 7FA-05 Siemens F(5) M 501GAC	255 – 264 MW	N/A	N/A	N/A	N/A	N/A	N/A
5	USEPA R6	N/A (submitted 11-26-2012)	NRG Texas Power LLC SR Berton Unit 5 La Porte, Texas	2	GE 7FA-05	255 MW	N/A	N/A	N/A	N/A	N/A	N/A
6	USEPA R6	N/A (submitted 12-11-2012)	Formosa Plastics Corporation, Texas Point Comfort Complex Point Comfort, TX	2	GE 7EA	105.5 MW	Combined cycle operation Efficient design	11,650	927,032	11,650	Btu/kWh (HHV, gross)	Fuel monitoring
7	USEPA R6	N/A (submitted 2-1-2013)	Golden Spread Electric Cooperative Antelope Station Abernathy, TX	1	GE 7F 5-Series	202 MW	Efficient design	N/A	538,754	538,754	tpy CO2e	Monitoring electrical output
8	USEPA R6	N/A (submitted 2-15-2013)	Tenaska Brownsville Partners, LLC Tenaska Brownsville Generating Station Brownsville, TX	2	MHI 501GAC	800 MW (combined total)	Evaporative cooling Good operation and maintenance practices	5,744 (LHV)	3,170,092	914	lb CO2/MWh	Fuel monitoring Monitoring electrical output
										1,577,254	tpy CO2 (per turbine)	
9	USEPA R6	N/A (submitted 2-15-2013)	Victoria WLE LP Victoria Power Station Victoria, TX	1	MHI 501F	197 MW	Efficient design Instrumentation and control Inspection, maintenance, and calibration	7,679	1,071,912	7,679	Btu/kWh	Fuel monitoring
10	USEPA R6	N/A (submitted 2-28-2013)	Pinecrest Energy Center, LLC Pinecrest Energy Center Angelica County, TX	2	GE 7FA.05	183 MW	Combined cycle operation Efficient design Plant-wide energy efficient processes, practices, and designs	7,925	2,895,156	942.0	lb CO2/MWh	Fuel monitoring
					Siemens SGT6-5000F(4)	205 MW		7,649	2,799,546	909.2	lb CO2/MWh	
					Siemens SGT6-5000F(5)	232 MW		7,679	3,141,558	912.7	lb CO2/MWh	
11	USEPA R6	N/A (submitted 3-4-2013)	NRG Texas Power LLC P.H. Robinson Electric Generating Station Bacliff, TX	6	GE 7B	65 MW	Efficient design Periodic maintenance and tune-up Instrumentation and controls	N/A	549,666	1,600	lb CO2/MWh	N/A
										91,611	tpy CO2 (per turbine)	
12	USEPA R6	N/A (submitted 6-21-2013)	Indeck Wharton, LLC Wharton, LLC Indeck Wharton Energy Center Wharton County, TX	3	GE 7FA	650 MW (combined total)	N/A	N/A	963,035	0.64	ton/MWh (GE)	N/A
					Siemens SGT6 5000F				1,075,530	0.67	ton/MWh (Siemens)	
13	USEPA R6	N/A (submitted 6-26-2013)	Invenergy Thermal Development LLC Ector County Energy Center Ector County, TX	2	GE 7FA.03	165 MW	Efficient design	12,038	567,362	1,430.76	lb CO2/MWh	Fuel monitoring
					GE 7FA.05	193 MW		11,324		1,345.97	lb CO2/MWh	
14	USEPA R6	N/A (submitted 6-28-2013)	Southern Power Company Trinidad Generating Facility Trinidad, TX	?	Not selected	530 MW (combined total)	Efficient design	N/A	1,674,804	922	lb CO2/MWh	Fuel monitoring

Table C-1. Recently Issued Permits and Applications Under Review for Greenhouse Gases Emissions from Combustion Turbines (Continued)

No.	Permit Authority	Permit Number	Company Name Facility Name Location	# of Units	Unit Description Model	Capacity	Control Technology	Thermal Efficiency	PTE	Proposed BACT Limits		Monitoring
								BTU (HHV) per kWh (gross)	tpy CO_2e	Parameter	Units	
15	USEPA R6	N/A (submitted 9-13-2013)	The City of Austin dba Austin Energy Sand Hill Energy Center Del Valle, TX	1	GE 7FA	189 MW	Combined cycle operation Efficient design	N/A	1,461,818	13,872	Btu/kWh (HHV) (simple cycle gross)	Fuel monitoring
16	USEPA R6	N/A (submitted 11-8-2013)	Lon C. Hill, LP Lon C. Hill Power Station Corpus Christi, TX	4	Siemens SCC6-5000F 7FA.04/7FA.05	195-240 MW	Combined cycle operation Efficient design Fuel flow meter	7,730	2,513,690	7,730 830-920	Btu/kWh lb CO2/MWh	Fuel monitoring

Attachment 4 –
Revised Process Flow Diagrams

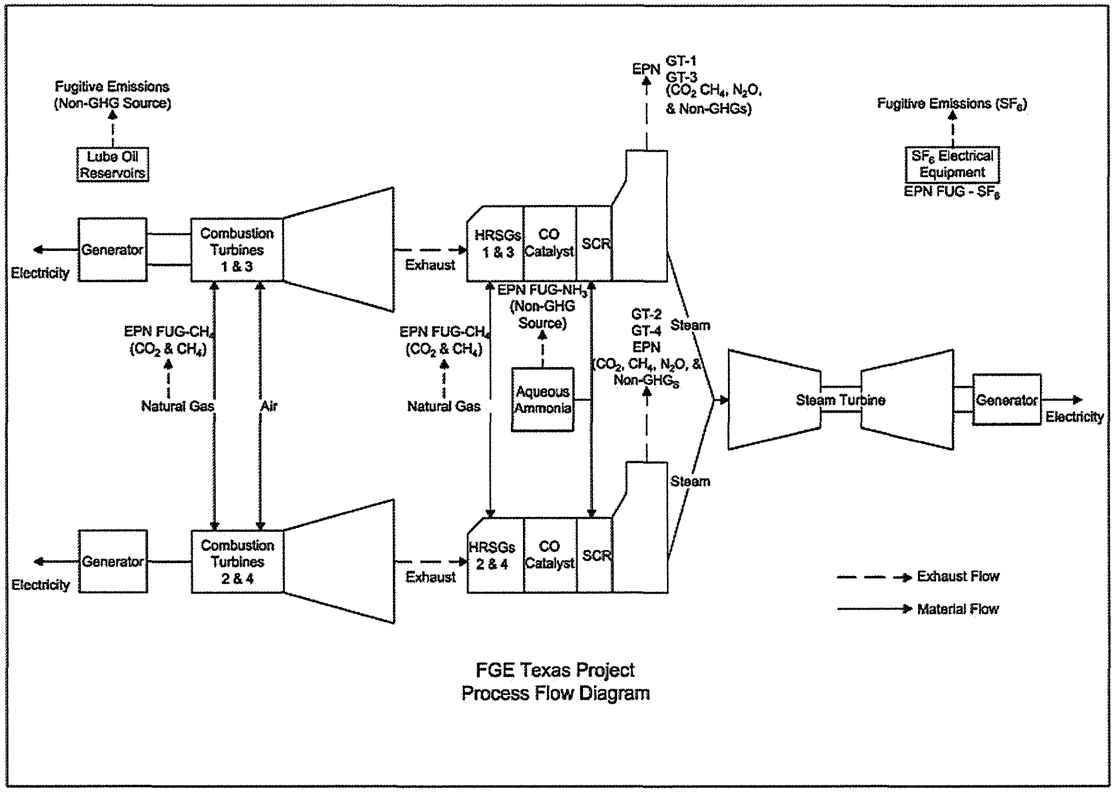

Figure 6. Combined-cycle combustion (Phase I-II).

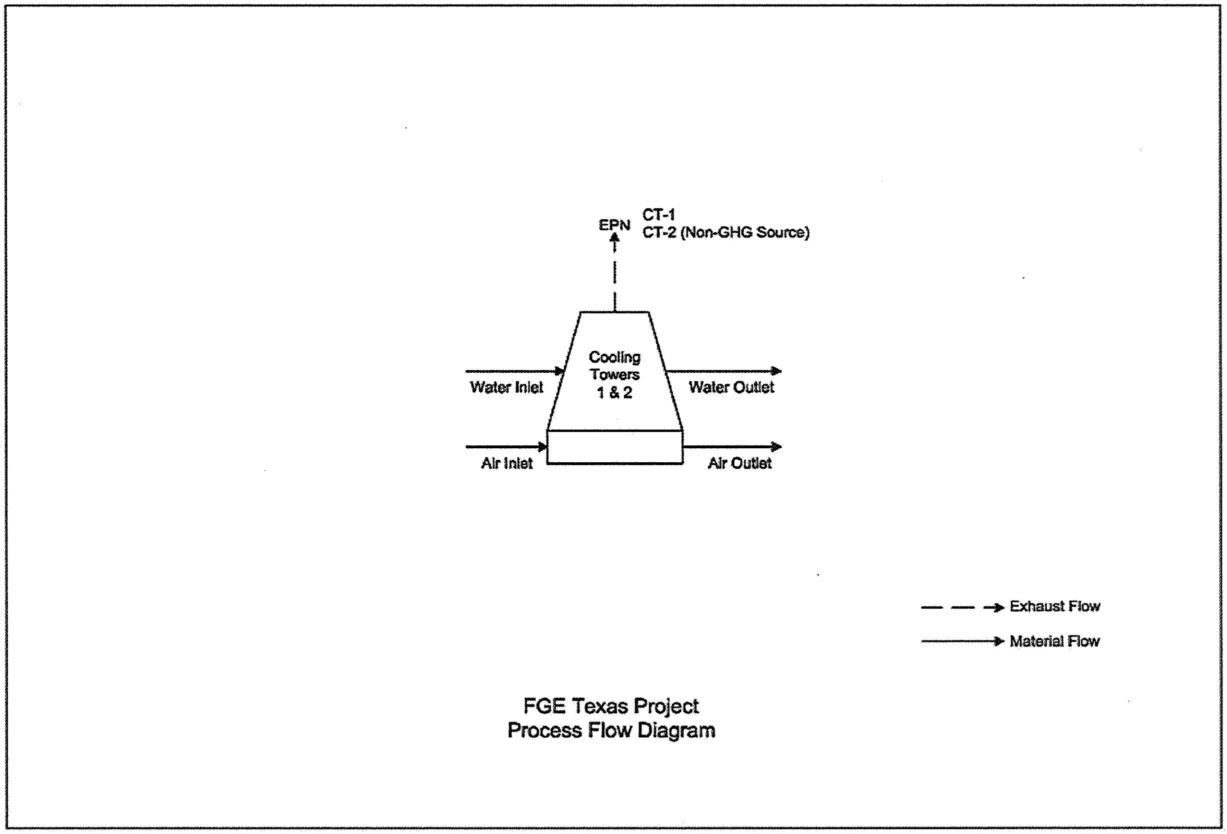

Figure 7. Cooling Tower.

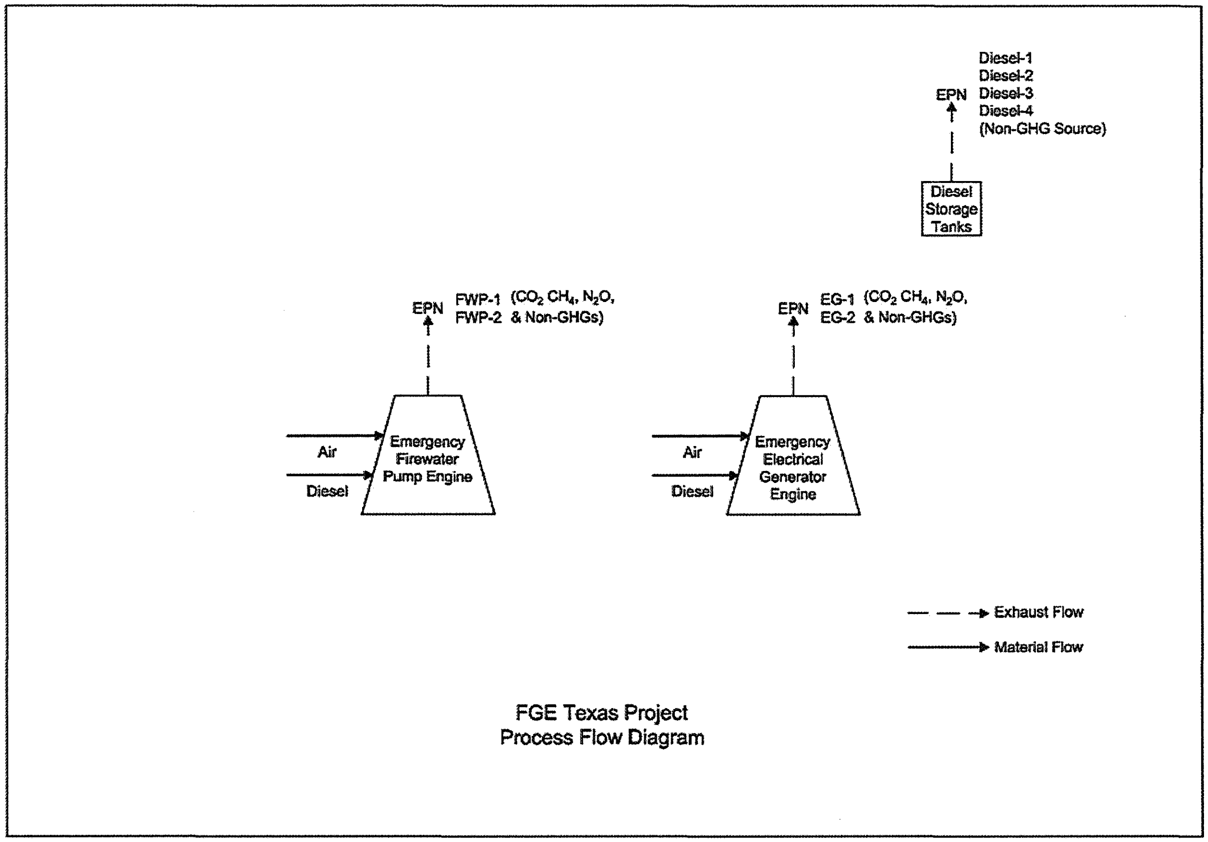

Figure 8. Emergency Diesel Engines.

Attachment 5 –
Reachable Degradation of Power Output and Heat Rate of a Typical Alstom GT24 Power Train (CBI)

THIS INFORMATION HAS BEEN REMOVED FROM THIS PUBLIC DOCUMENT AND SUBMITTED UNDER SEPARATE COVER IN WHICH THE APPLICANT ASSERTS THE MATERIAL AND INFORMATION IS CONFIDENTIAL BUSINESS INFORMATION.

Attachment 6 –
Updated Emission Tables

FGE Texas Project
Emission Calculations

Table 1 - Combined Cycle Combustion Turbine Test Data

Case	1	2a	2b	3	4	5	6	7	8	9a	9b
Load	100%	100%	100%	90%	80%	70%	60%	50%	LLOC	100%	100%
EC	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
HF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
DF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON
Temperature (°F)	95	95	95	95	95	95	95	95	95	5	5
Relative Humidity (%)	20%	20%	20%	20%	20%	20%	20%	20%	20%	55%	55%
Gross Output at CT Generator, per turbine (kW)	201,378	166,877	201,378	165,316	146,541	128,223	109,906	91,842	3,132	237,360	237,360
Gross Output at ST Generator (kW)	325,288	319,505	221,705	199,814	188,636	172,562	159,268	145,749	57,806	239,425	336,011
Gross Power Output (kW) [1]	728,044	653,259	624,461	530,446	481,718	429,008	379,080	329,433	64,070	714,145	810,731
Total Heat Input - LHV (mmBtu/hr)	4,420.4	3,945.6	3,635.6	3,057.0	2,781.8	2,525.2	2,272.3	2,015.7	689.9	4,124.1	4,860.0
Total Heat Input - HHV (mmBtu/hr)	4,905.3	4,378.4	4,034.4	3,392.4	3,087.0	2,802.2	2,521.6	2,236.8	765.6	4,576.5	5,393.2
Heat Rate - LHV (Btu/kWh) [2]	6,072	6,040	5,822	5,763	5,775	5,886	5,994	6,119	10,768	5,775	5,995
Heat Rate - HHV (Btu/kWh) [2]	6,738	6,702	6,461	6,395	6,408	6,532	6,652	6,790	11,949	6,408	6,652
Thermal Efficiency - LHV basis (%) [3]	56.2%	56.5%	58.6%	59.2%	59.1%	58.0%	56.9%	55.8%	31.7%	59.1%	56.9%
Thermal Efficiency - HHV basis (%) [3]	50.6%	50.9%	52.8%	53.4%	53.2%	52.2%	51.3%	50.3%	28.6%	53.2%	51.3%
CO_2 Emissions, per turbine (lb/hr)	299,889	290,283	237,400	207,597	189,304	171,664	154,567	137,093	47,291	280,201	333,269
lb CO_2 / MWh [4]	824	889	760	783	786	800	815	832	1,476	785	822
Average (all cases)		*870*		*lb CO_2 / MWh*		*6,364*		*Btu/kW-hr (LHV)*	*7,063*		*Btu/kW-hr (HHV)*
Average (all operating - excluding Case 8)		*810*		*lb CO_2 / MWh*		*6,423*		*Btu/kW-hr (LHV)*	*7,128*		*Btu/kW-hr (HHV)*
Average (100% Operation)		*816*		*lb CO_2 / MWh*		*5,941*		*Btu/kW-hr (LHV)*	*6,592*		*Btu/kW-hr (HHV)*
Average (100% Operation & DF)		*845*		*lb CO_2 / MWh*		*6,035*		*Btu/kW-hr (LHV)*	*6,697*		*Btu/kW-hr (HHV)*
Range (all cases)		*760*	*1,476*	*lb CO_2 / MWh*		*5,763*	*10,768*	*Btu/kW-hr (LHV)*	*6,395*	*11,949*	*Btu/kW-hr (HHV)*
Range (all operating - excluding Case 8)		*760*	*889*	*lb CO_2 / MWh*		*5,763*	*6,119*	*Btu/kW-hr (LHV)*	*6,395*	*6,790*	*Btu/kW-hr (HHV)*
Range (100% Operation)		*760*	*889*	*lb CO_2 / MWh*		*5,775*	*6,072*	*Btu/kW-hr (LHV)*	*6,408*	*6,738*	*Btu/kW-hr (HHV)*
Range (100% Operation & DF)		*822*	*889*	*lb CO_2 / MWh*		*822*	*6,072*	*Btu/kW-hr (LHV)*	*6,652*	*6,738*	*Btu/kW-hr (HHV)*

LLOC = Low-load Operating Condition
EC = Evaporative Cooling
HF = High Fogging
DF = Duct Firing

FGE Texas Project
Emission Calculations

Table 2 - Combustion Turbines (Combined Cycle) Emissions

Alstom GT24 Two-on-One Multi Shaft Natural Gas Turbine Potential to Emit (EPN: GT-1, GT-2, GT-3, and GT-4)

Assumptions	Value		Units
	Combined Cycle, both turbines w/ duct burners	*Combined Cycle, per turbine basis*	
Power Output [1]	474,720	237,360	kW
Heat Input, LHV [1]	4,860	2,430	mmBtu/hr
Heat Input, HHV [1]	5,393	2,697	mmBtu/hr
Annual Hours of Operation (Total)	8,760	8,760	hr/yr

Pollutant [1]	Combined Cycle - Single Turbine		
	Emission Factor		Annual Emissions
	lb/hr	*lb/mmBtu*	tpy
CO_2	333,269	-	1,459,718
CH_4 [2]	14.50	-	63.51
N_2O [3]	0.59	2.20E-04	2.60
CO_2e [4]			*1,462,080*

[1] Alstom turbine performance data represents the maximum value from all normal and LLOC operating scenarios. A copy of the performance test data is included in Appendix B of the application submittal.

[2] Assumed all unburned hydrocarbon (UHC) emissions as CH_4.

[3] N_2O emission factor from 40 CFR 98 Subpart C, Table C-2 for natural gas. For conservatism, the higher heating value (HHV) was used.

[4] Global warming potentials obtained from Table A-1 to Subpart 98 - Global Warming Potentials
Equation A-1 $CO2e = \sum GHGi \times GWPi$
Where:
CO2e = Carbon dioxide equivalent (tons/year)
GHGi = Mass emissions of each GHG (tons/year)
GWPi = Global warming potential for each GHG

FGE Power, LLC
FGE Texas Project
Emission Calculations

Table 3 - Maintenance, Start-up, and Shutdown (MSS) Emissions

Assumptions (MSS)		
Parameter	*Value*	*Units*
Max. No. of SUSD per day (per CT) [1]	1	events/day/CT
Max. No. of SUSD per year (per CT) [1]	365	events/yr/CT
Max. fuel heat input during start-up (per CT) [2]	820	(MMBtu/hr, HHV)
CH_4 emissions per start-up event [3]	1,735.0	(lb/start-up event)
CH_4 emissions per shutdown event [3]	510.0	(lb/shutdown event)

Pollutant	Start-up CO_2 Emissions (per turbine)	Start-up CO_2 Emissions (project total)
	ton/hr [4]	*ton/hr*
CO_2	48	192

Pollutant	MSS GHG Emissions (per turbine)		MSS GHG Emissions (project total)	
	lb/event [5]	*tpy* [6]	*lb/event* [7]	*tpy* [7]
CO_2	143,907	26,263	575,627	105,052
CH_4	2,245	410	8,980	1,639
CO_2e	200,032	36,506	1,375,753	251,075

[1] Maximum hourly MSS emissions assume the worst-case scenario of one (1) start-up and one (1) shutdown event per day per combustion turbine.

[2] According to the combustion turbine vendor, the maximum hourly fuel heat input required during hot start at 95 °F as 820 MMBtu/hr (HHV) per combustion turbine. Note that the duration of hot start is 56 minutes from ignition to compliance.

[3] The CH_4 SUSD emissions are conservatively assumed to be 100% of the Unburned Hydrocarbon (UHC) emissions provided by Alstom. SUSD emissions are provided in Appendix B of the application submittal. The hot start CH_4 emissions were chosen as the most conservative representation of emissions.

[4] Start-up CO_2 Emissions (ton/hr) = Max. fuel heat input during start-up (per CT) (MMBtu/hr) x 53.09 kg CO_2/MMBtu * 2.205 (lb/kg) / 2,000 (lb/ton)

[5] CO_2 Emissions (lb/event) = Max. fuel heat input during start-up (per CT) (MMBtu/hr) x 1.5 x 53.09 kg CO_2/MMBtu * 2.205 (lb/kg)
[The duration of a hot start is 56 minutes from ignition to compliance and the duration of a shutdown is 30 minutes; therefore the maximum fuel heat input during start-up times 1.5 is representative of the heat input of the event i.e., start-up plus shutdown).]

CH_4 Emissions (lb/event) = CH_4 Start-up Emissions (lb/start-up event) + CH_4 Shutdown Emissions (lb/shutdown event)

[6] Annual emissions (tpy) = Emissions (lb/events) * Events (events/yr) / 2,000 (lb/ton)

[7] Global warming potentials obtained from Table A-1 to Subpart 98 - Global Warming Potentials
Equation A-1 $CO_2e = \sum GHGi \times GWPi$
Where:
CO_2e = Carbon dioxide equivalent (tons/year)
GHGi = Mass emissions of each GHG (tons/year)
GWPi = Global warming potential for each GHG

FGE Texas Project
Emission Calculations

Table 4 - Diesel Engine Potential to Emit

Assumptions	Value		Units
	Firewater Pump	*Emergency Generator*	
Power Output [1]	389	900	bhp
Heat Input [2]	2.7	6.3	mmBtu/hr
Annual Hours of Operation (Total)	52	52	hrs/yr

Pollutant	**Emergency Firewater Pump Engine - Single Engine**			**Emergency Electrical Generator Engine - Single Engine**		
	Emission Factor [3,4]	**Hourly Emissions**	**Annual Emissions**	**Emission Factor [3,4]**	**Hourly Emissions**	**Annual Emissions**
	kg/mmBtu	***lb/hr***	***tpy***	***kg/mmBtu***	***lb/hr***	***tpy***
CO_2	73.96	444.07	11.55	73.96	1,027.42	26.71
CH_4	3.00E-03	0.02	0.00	3.00E-03	0.04	0.00
N_2O	6.00E-04	0.00	0.00	6.00E-04	0.01	0.00
CO_2e [5]		*445.60*	*11.59*		*1,030.94*	*26.80*

[1] Actual engines not yet selected; therefore, engines sized for maximum expected need for predicated applications. Specific engine manufacturer specifications will be provided when actual engines are chosen.

[2] Heat input calculated assuming a brake-specific fuel capacity of 7,000 Btu/hp-hr.
Estimated Heat Input (mmBtu/hr) = Average Brake-Specific Fuel Consumption (BSFC) (Btu/hp-hr) * Maximum Power Output (hp) * (1 mmBtu/1,000,000 Btu)

[3] CO_2 emission factor obtained from 40 CFR 98 Subpart C, Table C-1 for diesel (Distillate Fuel Oil No. 2).

[4] CH_4 and N_2O emission factors from 40 CFR 98 Subpart C, Table C-2 for diesel. For conservatism, the higher heating value (HHV) was used.

[5] Global warming potentials obtained from Table A-1 to Subpart 98 - Global Warming Potentials
Equation A-1 $CO_2e = \sum GHGi \times GWPi$
Where:
CO_2e = Carbon dioxide equivalent (tons/year)
GHGi = Mass emissions of each GHG (tons/year)
GWPi = Global warming potential for each GHG

FGE Texas Project
Emission Calculations

Table 5 - Natural Gas Fugitive Emissions (EPN: FUG-CH4)

Assumptions

Parameter	***Value***	***Units***
CH_4 Content of Natural Gas [1]	0.975	vol%
CO_2 content of Natural Gas [1]	1.1E-02	vol%
Conversion factor for CH_4 (scf to metric tones) [1]	0.0004030	
Conversion factor for CO_2 (scf to metric tones) [1]	0.00005262	
Conversion factor (metric tones to tons)	1.102	
GWP for CH_4	25	
GWP for CO_2	1	
Annual Hours of Operation	8,760	(hr/yr)

Equipment Type	Emission Factor [1]	Component Count (per Alstom Skid) [2]	Component Count (Outside Alstom Skid) [2]	Total Estimated Component Count (per power block) [3]	Fugitive CH_4 Emissions (per power block) [4]			Fugitive CO_2 Emissions (per power block) [4]			Total Fugitive CO_2e Emissions (per power block) [5]	
	(scf/hr/source)				(CO_2e tpy)	*(tpy)*	*(lb/hr)*	(CO_2e tpy)	*(tpy)*	*(lb/hr)*	*(tpy)*	*(lb/hr)*
Connector	0.017	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flanges	0.121	38	98	170	78.02	3.12	0.71	0.68	0.03	0.01	78.70	17.97
Open-ended lines	0.031	7	35	53	6.17	0.25	0.06	0.02	0.00	0.00	6.19	1.41
Sampling Connections	0.121	2	0	3	1.15	0.05	0.01	0.00	0.00	0.00	1.15	0.26
Pump seals	13.300	1	0	1	63.06	2.52	0.58	0.00	0.00	0.00	63.06	14.40
Pressure Relief Valve	0.193	0	3	4	2.75	0.11	0.03	0.00	0.00	0.00	2.75	0.63
Valves	0.121	34	65	124	56.80	2.27	0.52	0.36	0.01	0.00	57.16	13.05
Total	-	-	-	-	**207.95**	**8.32**	**1.90**	**1.06**	**0.04**	**0.01**	**209.00**	**47.72**

[1] Factors obtained from 40 CFR part 98 subpart W, Table W-1A - *Default Whole Gas Emission Factors for Onshore Petroleum and Natural Gas Production.* Emission factor for Valve was used for Flanges and Sampling Connections.

[2] Component count estimates for piping in both aqueous ammonia and natural gas service associated with the Alstom Skid (on a per skid baisis) provided by Mr. Sandeep Bhosale (Alstom) to Mr. Brad Sohm (SWCA) via email on November 16, 2012. All other component coun ammonia and natural gas service (per power block) provided by Mr. Greg Tardanico (SNC Lavalin) to Mr. Brad Sohm (SWCA) via email on November 16, 2012.

[3] Total component counts include the Alstom Skid plus Outside of Alstom Skid , with a 25% safety factor.

[4] 40 CFR part 98 subpart W Equation W-1: Mass (tpy CO_2e) = Count x EF (scf/hr/source) x GHG Concentrations (vol%) x Conv (scf to metric tones) x annual hours of operation (hr/yr). Note emissions have been converted from metric tones to U.S. tons.
Mass GHG (tpy) = Mass (CO_2e tpy) / GWP
Mass GHG (lb/hr) = Mass (tpy) * 2,000 (lb/ton) / Annual Hours of Operation (hr/yr)

[5] Global warming potentials obtained from Table A-1 to Subpart 98 - Global Warming Potentials
Equation A-1 $CO_2e = \sum GHGi \times GWPi$
Where:
CO_2e = Carbon dioxide equivalent (tons/year)
GHGi = Mass emissions of each GHG (tons/year)
GWPi = Global warming potential for each GHG

Table 5
Electric Equipment Insulated with SF_6 Fugitive Emissions (EPN: FUG-SF6)

Breaker Type	Quantity	SF_6 Capacity [1]		Fugitive SF_6 Emissions [2]	Fugitive SF_6 Emissions [2]	Fugitive CO_2e Emissions [3]
		each	total			
		(lb)	*(lb)*	*(lb/yr)*	*(ton/yr)*	*(ton/yr)*
362 kV	12	27.5	330	1.65	0.000825	18.81
24 kV	16	8.25	132	0.66	0.00033	7.524
Total	**28**	-	**462**	**2.31**	**0.001155**	**26.334**

[1] Circuit breaker capacity data provided by the vendor.

[2] Circuit breaker fugitive emissions based on 0.5% annual leak rate as cited in J. Blackman, M. Averyt, and Z. Taylor, "SF_6 Leak Rates from High Voltage Circuit Breakers – EPA Investigates Potential Greenhouse Gas Emission Source," available at: http://www.epa.gov/electricpower-sf6/documents/leakrates_circuitbreakers.pdf.

[3] Global warming potentials obtained from Table A-1 to Subpart 98 - Global Warming Potentials
Equation A-1 $CO_2e = \sum GHGi \times GWPi$
Where:
CO_2e = Carbon dioxide equivalent (tons/year)
GHGi = Mass emissions of each GHG (tons/year)
GWPi = Global warming potential for each GHG

FGE Texas Project
Emission Calculations

Table 6 - Greenhouse Gases Potential to Emit

Greenhouse Gas	Global Warming Potential [1]
CO_2	1
CH_4	25
N_2O	298
SF_6	22,800

Emission Source [2]	CO_2	CH_4	N_2O	SF_6	CO_2e [3]
	tpy	*tpy*	*tpy*	*tpy*	*tpy*
Phase 1					
GT-1	1,459,718	473.22	2.60	-	1,472,323
GT-2	1,459,718	473.22	2.60	-	1,472,323
FWP-1	12	4.68E-04	9.37E-05	-	12
EG-1	27	1.08E-03	2.17E-04	-	27
FUG-CH4	0.04	8.32	-	-	209
FUG-SF6	-	-	-	1.16E-03	26
Total	***2,919,475***	***954.76***	***5.20***	***-***	***2,944,920***
Phase 2					
GT-1	1,459,718	473.22	2.60	-	1,472,323
GT-2	1,459,718	473.22	2.60	-	1,472,323
GT-3	1,459,718	473.22	2.60	-	1,472,323
GT-4	1,459,718	473.22	2.60	-	1,472,323
FWP-1	12	4.68E-04	9.37E-05	-	12
FWP-2	12	4.68E-04	9.37E-05	-	12
EG-1	27	1.08E-03	2.17E-04	-	27
EG-2	27	1.08E-03	2.17E-04	-	27
FUG-CH4	0.08	16.64	-	-	418
FUG-SF6	-	-	-	1.16E-03	26
Total	***5,838,949***	***1,909.53***	***10.39***	***-***	***5,889,813***

[1] 40 CFR 98 Subpart A, Table A-1

[2] GT-1, GT-2, GT-3, and GT-4 CH_4 and CO_2e emissions include both "normal " operations and MSS emissions.

[3] Global warming potentials obtained from Table A-1 to Subpart 98 - Global Warming Potentials
Equation A-1 $CO_2e = \sum GHGi \times GWPi$
Where:
CO_2e = Carbon dioxide equivalent (tons/year)
GHGi = Mass emissions of each GHG (tons/year)
GWPi = Global warming potential for each GHG

FGE Texas Project
Emission Calculations

Table 7 - Design Heat Rate Limit for Alstom GT24 (w/o duct firing)

Parameter	*Value*	*Units*
Base Heat Rate (gross, w/o duct firing) [1]	6,790	Btu/kWh (HHV)
Design Margin	3.3	%
Performance Margin	6.0	%
Degradation Margin	3.0	%
Calculated Base Heat Input Rate w/ Compliance Margins (gross) [2]	*7,625*	*Btu/kWh (HHV)*

Emission Point Number (EPN)	Base Heat Rate (net, w/o duct firing) (Btu/kWh)	Heat Input Required to Produce 1 MWh (mmBtu/MWh)	Pollutant	Emission Factor (kg/mmBtu) [3]	lb GHG/MWh [4]	Global Warming Potential [5]	lb CO_2e/MWh [6]
GT-1	7,625	7.63	CO_2	-	832	1	832
			CH_4	1.E-03	1.68E-02	25	4.20E-01
			N_2O	1.E-04	1.68E-03	298	5.01E-01
GT-2	7,625	7.63	CO_2	-	832	1	832
			CH_4	1.E-03	1.68E-02	25	4.20E-01
			N_2O	1.E-04	1.68E-03	298	5.01E-01
GT-3	7,625	7.63	CO_2	-	832	1	832
			CH_4	1.E-03	1.68E-02	25	4.20E-01
			N_2O	1.E-04	1.68E-03	298	5.01E-01
GT-4	7,625	7.63	CO_2	-	832	1	832
			CH_4	1.E-03	1.68E-02	25	4.20E-01
			N_2O	1.E-04	1.68E-03	298	5.01E-01
				Total (per turbine)	**832**		**833**

[1] Alstom turbine performance data represents the maximum value from all baseload operating scenarios without duct firing. A copy of the estimated combined cycle process and emissions data is included in Appendix B.

[2] Calculated Base Heat Input Rate w/ Compliance Margins (gross) = Base Heat Rate (Btu/kWH) * [1 + (Design Margin (%) + Performance Margin (%) + Degradation Margin (%))]

[3] CH_4 and N_2O emission factor from 40 CFR 98 Subpart C, Table C-2 for natural gas. For conservatism, the higher heating value (HHV) was used.

[4] lb GHG/MWh = Heat Input Required to Produce 1 MWh (mmBtu/MWh) * Emission Factor (kg/mmBtu) * 2.205 (lb/kg)

[5] Global warming potentials obtained from Table A-1 to Subpart 98 - Global Warming Potentials
Equation A-1 $CO_2e = \sum GHGi \times GWPi$
Where:
CO_2e = Carbon dioxide equivalent (tons/year)
GHGi = Mass emissions of each GHG (tons/year)
GWPi = Global warming potential for each GHG

[6] lb CO_2e/MWh = lb GHG/MWh * Global Warming Potential

FGE Power, LLC
FGE Texas Project
Emission Calculations

Table 8 - Design Heat Rate Limit for Alstom GT24 (w/duct firing)

Parameter	*Value*	*Units*
Base Heat Rate (gross, w/duct firing) [1]	6,738	Btu/kWh (HHV)
Design Margin	3.3	%
Performance Margin	6.0	%
Degradation Margin	3.0	%
Calculated Base Heat Input Rate w/ Compliance Margins (gross) [2]	*7,567*	*Btu/kWh (HHV)*

Emission Point Number (EPN)	Base Heat Rate (net, w/o duct firing) (Btu/kWh)	Heat Input Required to Produce 1 MWh (mmBtu/MWh)	Pollutant	Emission Factor (kg/mmBtu) [3]	lb GHG/MWh [4]	Global Warming Potential [5]	lb CO_2e/MWh [6]
GT-1	7,567	7.57	CO_2	-	889	1	889
			CH_4	1.E-03	1.67E-02	25	4.17E-01
			N_2O	1.E-04	1.67E-03	298	4.97E-01
GT-2	7,567	7.57	CO_2	-	889	1	889
			CH_4	1.E-03	1.67E-02	25	4.17E-01
			N_2O	1.E-04	1.67E-03	298	4.97E-01
GT-3	7,567	7.57	CO_2	-	889	1	889
			CH_4	1.E-03	1.67E-02	25	4.17E-01
			N_2O	1.E-04	1.67E-03	298	4.97E-01
GT-4	7,567	7.57	CO_2	-	889	1	889
			CH_4	1.E-03	1.67E-02	25	4.17E-01
			N_2O	1.E-04	1.67E-03	298	4.97E-01
				Total (per turbine)	**889**		**890**

[1] Alstom turbine performance data represents the maximum value from all baseload operating scenarios with duct firing. A copy of the estimated combined cycle process and emissions data is included in Appendix B.

[2] Calculated Base Heat Input Rate w/ Compliance Margins (net) = Base Net Heat Rate (Btu/kWH) * [1 + (Design Margin (%) + Performance Margin (%) + Degradation Margin (%))]

[3] CH_4 and N_2O emission factor from 40 CFR 98 Subpart C, Table C-2 for natural gas. For conservatism, the higher heating value (HHV) was used.

[4] lb GHG/MWh = Heat Input Required to Produce 1 MWh (mmBtu/MWh) * Emission Factor (kg/mmBtu) * 2.205 (lb/kg)

[5] Global warming potentials obtained from Table A-1 to Subpart 98 - Global Warming Potentials
Equation A-1 $CO_2e = \sum GHGi \times GWPi$
Where:
CO_2e = Carbon dioxide equivalent (tons/year)
GHGi = Mass emissions of each GHG (tons/year)
GWPi = Global warming potential for each GHG

[6] lb CO_2e/MWh = lb GHG/MWh * Global Warming Potential

Attachment 7 –
Updated CCS Cost Estimated (CBI)

THIS INFORMATION HAS BEEN REMOVED FROM THIS PUBLIC DOCUMENT AND SUBMITTED UNDER SEPARATE COVER IN WHICH THE APPLICANT ASSERTS THE MATERIAL AND INFORMATION IS CONFIDENTIAL BUSINESS INFORMATION.