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HILL COUNTRY ENVIRONMENTAL, INC.

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Mr. Carl Edlund, PE
Multimedia Planning and Permitting Division
U.S. EPA (6PD-R)
1445 Ross Ave. Ste. 1200
Dallas, Texas 75202-2733

**Re: Calhoun Port Authority, ES Joslin Power Station, Point Comfort, Texas
Greenhouse Gas Prevention of Significant Deterioration Permit
Response to Request for Information Dated August 23, 2012**

Dear Mr. Edlund:

On behalf of Calhoun Port Authority (CPA), Hill Country Environmental (HCE) is submitting this response to your request dated August 23, 2012 for additional information. The responses below are numbered according to your correspondence.

1. CPA is proposing a 740 lb of CO₂/MWh emission rate on a net electrical output basis as the output based emission limit. The updated emission limit can be found on page 10 of the *Greenhouse Gases Best Available Control Technology (BACT) Review* document attached with this response.
2. A comparison of the GE 7FA turbine and Siemens SGT6-5000F turbine has been included as a part of the *Greenhouse Gases Best Available Control Technology (BACT) Review* to justify the use of GE 7FA turbine for the project.

In order to maintain optimum operating conditions to reduce GHG emissions, CPA is proposing an efficiency based limitation instead of a heat input based limitation. The proposed plant heat input rate will meet the proposed efficiency based emission limit; hence, a separate heat input based emission limit is not proposed for the project.

3. A revised process flow diagram is attached that includes the GHG emissions sources with corresponding emission point numbers.
4. The GE 7FA turbines are equipped with "Model Based Controls" for reading turbine operating parameters and performing necessary corrections to optimize combustion/operation of the turbine. The "Model Based Controls" use various sensors to gather operating conditions data like compressor exit temperature, pressure drop across the turbine, exhaust temperature, fuel flow etc. to determine performance of the turbines. As the ambient conditions and load conditions vary regularly, the "Model Based Controls" monitor the operating conditions and make changes to the input parameters like fuel flow and air flow to maintain optimum operating conditions. "Model Based Controls" ensure efficient operation of turbines on a real time basis by ensuring good combustion.

A comparative benchmark data for combustion turbine similar to GE 7FA turbine is provided in *Greenhouse Gases Best Available Control Technology (BACT) Review* and can be found on Page 2 of the document.

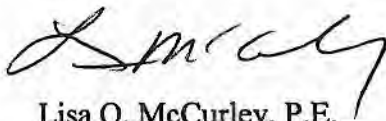
5. A cost analysis of the Carbon Capture and Storage (CCS) technology for the project has been included in the *Greenhouse Gases Best Available Control Technology (BACT) Review* and is attached with this submittal.
6. The GHG emissions from the turbines during startup/shutdown (SS) will be significantly lower than the GHG emissions during normal operations as the fuel flow rate is low and incomplete combustion takes place during SS operations resulting in lower emission rate of CO₂. The GHG emissions are considered to be worse during normal operations; therefore, annual GHG emissions estimated are based on turbines operating in the normal operations mode for 8,760 hours per year.
7. A BACT analysis for the "Fugitive Area" has been included in the *Greenhouse Gases Best Available Control Technology (BACT) Review* attached with this submittal.

The title of the *Best Available Control Technology (BACT) Review* document included in the original submittal dated June 15, 2012 has been revised to read *Greenhouse Gases (GHG) Best Available Control Technology (BACT) Review* and is attached with this submittal. Also, find attached the revised copy of the *Process Flow Diagram* revised to include other GHG sources.

The set of documents included with this submittal replace the corresponding previously submitted documents in its entirety.

Please contact Mr. Adi Bhat at 512.327.2725 or at Adi@hillcountryenv.com with any questions or comments.

Sincerely,



Lisa O. McCurley, P.E.
President

cc: Charles R. Hausmann, Port Director, Calhoun Port Authority
Mr. Mike Wilson, P.E., Director, Air Permits Division, TCEQ
Ms. Melanie Magee, EPA Region 6

List of Attachments:

Application Completeness Determination
Greenhouse Gases (GHG) Emission Point Diagram
Greenhouse Gases Best Available Control Technology (BACT) Review



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TX 75202-2733

Mr. Charles R. Hausmann
Port Director
Calhoun Port Authority
P.O. Box 397
Point Comfort, TX 77978

AUG 23 2012

RE: Application Completeness Determination for Calhoun Port Authority (CPA)
Greenhouse Gas Prevention of Significant Deterioration Permit
ES Joslin Power Station, Point Comfort, Texas

Dear Mr. Hausmann:

This letter is in response to your application received by this office on June 20, 2012, for a Greenhouse Gas (GHG) Prevention of Significant Deterioration (PSD) permit. After our initial review of the application and supporting information, we have determined that this application is incomplete based on the requirements of 40 CFR 124 and additional information is required to begin the processing of the application. Enclosed is a list of the information required (see Enclosure).

Upon receipt of the additional information, the Environmental Protection Agency (EPA) will prepare a completeness determination. The requested information is necessary for EPA to develop a Statement of Basis and Rationale for the terms and conditions for the requisite permit. As we develop our preliminary determination, it may be necessary for EPA to request additional clarifying or supporting information. If the supporting information substantially changes the original scope of the permit application, an amendment or new application may be required.

Although not required as a part of our completeness determination, the EPA may not issue a final permit without determining that there will be no effects on endangered species or until it has completed consultation under Section 7 of the Endangered Species Act (16 USC 1536). In addition, the EPA must undergo consultation pursuant to Section 106 of the National Historic Preservation Act (16 USC 470f). To expedite these consultations, the EPA requests that permit applicants provide a Biological Assessment and a cultural resources report covering the project and action area.

If you have any questions concerning the review of your application, please contact Melanie Magee of my staff at (214) 665-7161.

Sincerely yours,

A handwritten signature in dark ink, appearing to read 'C. Edlund', written in a cursive style.

Carl E. Edlund, P.E.
Director
Multimedia Planning and
Permitting Division

Enclosure

cc: Mr. Mike Wilson, P.E.
Director, Air Permits Division
Texas Commission on Environmental Quality

ENCLOSURE

EPA Completeness Comments Calhoun Port Authority – ES Joslin Power Station, Point Comfort, Texas Application for Greenhouse Gas Prevention of Significant Deterioration Permit

1. Being mindful of EPA's PSD and Title V Permitting Guidance for GHG dated March, 2011 on page 17, which states the following:

"The CAA and corresponding implementing regulations require that a permitting authority conduct a BACT analysis on a case-by-case basis, and the permitting authority must evaluate the amount of emissions reductions that each available emissions-reducing technology or technique would achieve, as well as the energy, environmental, economic and other costs associated with each technology or technique. Based on this assessment, the permitting authority must establish a numeric emissions limitation that reflects the maximum degree of reduction achievable for each pollutant subject to BACT through the application of the selected technology or technique. However, if the permitting authority determines that technical or economic limitations on the application of a measurement methodology would make a numerical emissions standard infeasible for one or more pollutants, it may establish design, equipment, work practices or operational standards to satisfy the BACT requirement."

In addition to the proposed BTU/kWh emission limit provided in the permit application, please propose an output based emission limitation or efficiency based limits for all PSD emission sources (e.g., lb or ton CO₂/MWh). Please provide an analysis that substantiates any reasons for infeasibility of a numerical emission limitation. For the emission sources where numerical emission limitations are infeasible, please propose an operating work practice standard that can be practically enforceable.

2. Please provide supplemental benchmark data that compares the energy efficiency of the selected GE 7FA gas turbine to similar or existing sources. Were other CTG/HSRG units considered for the purposed project from an energy efficiency/emission perspective? Please supplement the current BACT analysis to include the evaluation performed to determine selection. Please include comparative design data that includes heat load and efficiency data of the other CTG/HSRG's that were considered in addition to the one that was selected. (This information can be graphically represented). At what heat load will the combined cycle units operate? Please provide rationale that supports operating at the proposed heat load is energy efficient as BACT.
3. Please provide supplemental data on the process flow diagram that includes all GHG emission sources with corresponding emission source numbers (EPNs), i.e., fugitive emissions, emergency engines, etc.
4. What are the proposed recordkeeping requirements for the combustion turbines operating parameters? How will the air/fuel ratio be assured during operation of the combustion turbine, i.e., alarms, alerts, continuous monitoring, etc? Will O₂ or CO₂ analyzers be utilized? What will be the target ratio? Please provide more details of what operating parameters will be monitored

to ensure good combustion. What is the company's proposed compliance monitoring methodology? Please provide comparative benchmark data of the proposed combustion turbine with existing or similar combustion turbines in GHG per pound of exhaust gas.

5. Beginning on page 7 of 11 of the permit application, the cost estimates provided for the Carbon Capture and Storage (CCS) appear to rely on the August 2010 report entitled "Report of the Interagency Task Force on Carbon Capture and Storage." BACT is a case-by-case determination. Please provide site-specific facility data to evaluate and eliminate CCS from consideration. This material should contain detailed information on the quantity and concentration of CO₂ that is in the waste stream and the equipment for capture, storage and transportation. Please include cost of construction, operation and maintenance, cost per pound of CO₂ removed by the technologies evaluated and include the feasibility and cost analysis for storage or transportation for these options. Please discuss in detail any site specific safety or environmental impacts associated with such a removal system.
6. It is not clear from the permit application if GHG Maintenance, Startup and Shutdown (MSS) emissions are included in the Carbon Dioxide Equivalent GHG Emissions Summary presented in the table on page 1 of 1. Please provide supplemental data that includes these emission rates.
7. EPA notes that a 5-step BACT analysis was not included for the "Fugitive Area". A process description of the "Fugitive Area" is on page 4 of 4 of the permit application and also emission calculations. Please provide supplemental data 5-step BACT analysis for fugitives. Please include all TCEQ LDAR programs considered for this project, what was the basis for elimination and selection of the programs as part of your 5-step BACT analysis.

The diagram illustrates the combustion system for the 1000 MW gas turbine engine. It features three parallel gas turbine engines (GT1, GT2, GT3) and a common exhaust gas treatment system. Each engine consists of a Compressor Turbine (CTG), a Heat Recovery Steam Generator (HRSG), and a Selective Catalytic Reducer (SCR). The CTGs are connected to a common shaft that drives the Emergency Generator (EG1) and the Fire Water Pump (FWP). The HRSGs are connected to a common steam line that drives the Emergency Generator (EG2). The SCR units are connected to a common stack that emits CO₂, CH₄, and N₂O emissions. The diagram also shows the flow of NG supply, exhaust gases, and electricity. The system is designed to minimize emissions and maximize efficiency.

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Greenhouse Gases (GHG) Best Available Control Technology (BACT) Review**

Clean Air Act defines Best Available Control Technology (BACT) as:

Best available control technology means an emissions limitation (including a visible emission standard) based on the maximum degree of reduction for each pollutant subject to regulation under Act which would be emitted from any proposed major stationary source or major modification which the Administrator, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such source or modification through application of production processes or available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of such pollutant. In no event shall application of best available control technology result in emissions of any pollutant which would exceed the emissions allowed by any applicable standard under 40 CFR parts 60 and 61. If the Administrator determines that technological or economic limitations on the application of measurement methodology to a particular emissions unit would make the imposition of an emissions standard infeasible, a design, equipment, work practice, operational standard, or combination thereof, may be prescribed instead to satisfy the requirement for the application of best available control technology. Such standard shall, to the degree possible, set forth the emissions reduction achievable by implementation of such design, equipment, work practice or operation, and shall provide for compliance by means which achieve equivalent results.¹

Environmental Protection Agency's (EPA's) guidance on Prevention of Significant Deterioration (PSD) rules titled *PSD and Title V Permitting Guidance for Greenhouse Gases* recommends the use of a 5 step "top-down" approach to determine BACT for Greenhouse Gases (GHGs).²

The definition of BACT stated above references determining BACT for "each pollutant" individually; however, for the purposes of this project the predominant pollutant contributing to the GHGs is carbon dioxide (CO₂). CO₂ is the largest contributor towards CO₂e emissions (> 99%) and hence the most significant pollutant for reducing the impact of GHGs. Therefore, the 5 step "top down" approach outlined in this document will concentrate on determining BACT for CO₂.

The 5 steps in the "top down" approach suggested by EPA are as follows:

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

Each of the sources at the Calhoun Port Authority (CPA) – ES Joslin Power Plant contributing to GHG emissions have been analyzed for BACT according to the 5 step process. The analysis is summarized below:

¹ 40 Code of Federal Regulations §52.21(b)(12).

² *PSD and Title V Permitting Guidance for Greenhouse Gases*, EPA, March, 2011.

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BACT for Combined Cycle Power Generation

Step 1: Identify all available control technologies

Combustion Controls

Combined Cycle Power Generation

The EPA's guidance document for determination of BACT for GHGs considers overall energy efficiency of the operating units to be the key factor in BACT determination.³ In general, a more energy efficient technology burns less fuel than a less energy efficient technology on a per unit of output basis. CPA proposes to employ a combined cycle electricity generation unit which reuses heat from the exhaust gases of the combustion turbines to generate steam for the steam turbine generator. Reuse of heat to generate electricity makes the cogeneration plant energy efficient by producing more electricity for the same heat input, thus helping to reduce emissions of GHGs and other criteria pollutants. Therefore, combined cycle electric generating plants ("cogeneration") are considered to be the most energy efficient option. As single cycle generation is more energy intensive on a per unit electricity generation basis, cogeneration is considered to be the best available technology.

Use of pipeline natural gas is considered as the cleanest fuel for power generation⁴ and since CPA is proposing the cleanest fossil fuel, alternative fossil fuels have not been considered in this exercise.

Selection of GE Frame 7FA Combustion Turbine

In order to evaluate a suitable match for the requirements of CPA for the Joslin EGU project and to identify the technology/equipment with the least possible environmental impact, a comparison of the available combustion turbine technology has been performed. The two most popular turbines were compared for the purposes of the evaluation, General Electric (GE) 7FA turbine and Siemens SGT6-5000F turbine.

Output based comparison

	Power Output (MWh)	CO₂e Emission Rate (tons/year)	CO₂e Emission Rate⁽¹⁾ (tons/hour)	Turbine Efficiency (tons of CO₂e /MW)
GE 7FA	208	950,392	108.5	0.52
Siemens SGT6-5000F(4)	232 ⁵	1,451,771 ⁵	165.7 ⁵	0.71 ⁵

Notes: 1) CO₂e Emission Rate in tons per hour is calculated based on an annual operation time of 8,760 hours per year.

³ Parker, L., McCarthy, J., *EPA's BACT Guidance for Greenhouse Gases from Stationary Sources*, Congressional Research Service, November 22, 2010.

⁴ EPA's Natural Gas Webpage found at: <http://www.epa.gov/cleanenergy/energy-and-you/affect/natural-gas.html> (last accessed on June 7, 2012).

⁵ *Application for a Prevention of Significant Deterioration Air Quality Permit for Greenhouse Gas Emissions* submitted by Coronado Ventures for La Paloma Energy Center, LLC dated April 26, 2012.

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As discussed above, the power output efficiency of the Siemens turbine is approximately 0.71 tons of CO₂e per megawatt (MW) of electricity produced and that of the GE 7FA turbine is 0.52 tons of CO₂e per MW of electricity produced. Therefore, the emissions of GHGs from the GE 7FA turbine on power output are less than the emissions associated with the Siemens turbine. As the GE 7FA turbine is more efficient and better suited to the needs of the project, this turbine is proposed as the BACT for the project.

Combustion Turbine Generator (CTG) Energy Efficiency

The power generation plant configuration includes three GE Frame 7FA Combustion Turbine Generators (CTGs) with evaporative coolers and dry low NO_x combustors. The CTGs are natural gas fired rotary engines that extract energy from a flow of combusted gas. Fuel is mixed with air and ignited in the combustion chamber. Resulting combustion products are forced across the turbine section blading, spinning the turbine which in turn is connected to a generator providing the electrical output.

A search of the EPA's RACT/BACT/LAER clearinghouse for natural gas fired combined cycle combustion turbines was performed and no results are returned addressing BACT for GHGs. The EPA's climate change website references a GHG BACT analysis performed by Russell City Energy center for 612 Megawatt (MW) natural gas fired combined cycle power plant to be located in Hayward, California. The Russell City project includes a cogeneration unit configuration similar to the one proposed by CPA in this application. The analysis references an output based efficiency limit of seven thousand seven hundred and thirty (7,730) British Thermal Units per Kilowatt-hour (Btu/kWh) as BACT for GHG emissions.⁶

The three main factors influencing the overall efficiency of a turbine are compressor, combustion, and turbine design.

Compressor⁷: The compressor technology used for the turbines has been developed from prior heavy duty gas turbine platforms and is inspired from aviation compressor technology. As such these engines are highly efficient and consist of 14 stages specifically modeled for a higher flow rate, enabling greater output. The airfoil design is based on the proven aerodynamic configuration of the GE5, GE10, 5002E and 6C platforms. The airfoils utilize a proprietary, three-dimensional aerodynamic shape for improved efficiency. The first three stages of the compressor contain variable stator vanes that provide the gas turbine with a wider operating envelope. The compressor flow path has been planned to accommodate inlet conditioning with improved leading edge erosion tolerance. The rotor is bolted steel construction with two sets of durable concentric tie bolts specifically planned to improve the aerodynamic flow path. The air is directed into the compressor through a bell mouth to reduce inlet pressure loss and improve the overall combustion turbine efficiency. The "F" type combined cycle combustion turbines typically achieve a net thermal efficiency of 53% (LHV) and the "FA" type turbine technology has a 15.5 pressure ratio⁸ which increases the overall efficiency of the combustion turbine.

⁶ *GHG BACT Analysis Case Study, Russell City Energy Center, Calpine*, Originally published in November 2009. Updated on February 3, 2010 found at: http://www.epa.gov/oar/caaac/pdfs/RCEC_GHG_BACT_Analysis_Case_Study.pdf (last accessed on June 7, 2012)

⁷ Martin, R., Forry, D., Maier, S., and Hansen, C., *GE's Next 7FA Gas Turbine "Test and Validation"*, GE Energy, July 2011.

⁸ Chase, D.L, Kehoe, P.T, *GE Combined-Cycle Product Line and Performance*, GE Power Systems, GER-3574G, October 2000.

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Combustion: The turbines are equipped with multiple can-annular type combustors with film impingement cooling which increases the efficiency of the turbines.⁸ The 7FA model turbines are capable of efficient combustion of fuels to reduce NO_x emissions and are therefore classified as a low-NO_x emitting technology. 90% of gas fuel is injected through radial gas injection spokes in the premixer, and combustion air is mixed with the fuel in tubes within the fuel nozzles.⁹ The premixer tubes are part of the cap assembly.⁹ The fuel and air are thoroughly mixed, flow out of the five tubes at high velocity and enter the burning zone where lean, low-NO_x combustion occurs.⁹ The efficiency of the turbines is a function of the “Specific Power” (Power produced by the gas turbine per unit airflow). Improvements in combined-cycle thermal efficiency have developed primarily through the increases in gas turbine firing temperature, which have resulted from the development of high-temperature / high strength materials, corrosion-resistant coatings, and improved cooling technology.⁷ The GE 7FA turbines are equipped with “Model Based Controls” for reading turbine operating parameters and performing necessary corrections to optimize combustion/operation of the turbine. The “Model Based Controls” use various sensors to gather operating conditions data like compressor exit temperature, pressure drop across the turbine, exhaust temperature, fuel flow etc. to determine performance of the turbines. As the ambient conditions and load conditions vary regularly, the “Model Based Controls” monitor the operating conditions and make changes to the input parameters like fuel flow and air flow to maintain optimum operating conditions. “Model Based Controls” ensure efficient operation of turbines on a real time basis does ensuring good combustion.

Turbine Section: The 7FA model turbines are designed with high-efficiency blades and advanced construction to provide efficient utilization of burned fuel. Turbine materials, coatings and cooling systems enable reliable operation at high firing temperatures resulting in higher specific power and high efficiency for combined-cycle systems. The turbines are configured with open-loop cooling of the turbine hot gas path.⁸ Hot gas path components are in large part cooled by film cooling that uses air supplied from the compressor to improve output and efficiency.⁷ Proprietary three-dimensional aerodynamic air foil shapes and more efficient stage loadings of the turbines increases the overall efficiency.⁷ Improved cooling, efficiency sealing, and improved clearance further increase output of the combustion turbines.

The combined-cycle combustion turbines are also equipped with additional features to improve the efficiency and output of the turbines. Some of the design features have been summarized below:

Evaporative Cooling: Evaporative coolers are used with gas turbines to increase the density of the combustion air, thereby increasing power output. The air density increase is accomplished by evaporating water into the inlet air, which decreases its temperature and correspondingly increases its density.¹⁰ Increased density of the combustion air increases the power output of the turbines thus increasing efficiency. Evaporative coolers are useful in increasing the power output of the turbines during warm summer months.

⁹ Davis, L.B, Black, S.H, *Dry Low NO_x Combustion Systems for GE Heavy-Duty Gas Turbines*, GE Power Systems, GER-3568G, October 2000.

¹⁰ Johnson, R.S, Sr., P.E., *The Theory and Operation of Evaporative Coolers For Industrial Gas Turbine Installations*, THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, 345 E. 47 St., New York, N.Y. 10017, 88-GT-41, June 1988.

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Insulation: The turbines have a rated firing temperature of 2420 °F (1327 °C). As discussed earlier, higher operating temperatures provide higher efficiency for the turbines. These turbines are well insulated to prevent heat loss from the turbine casings, increasing the thermal efficiency and providing safe operating environment for the personnel working around it. Efficient insulation of the casing increases the efficiency of the turbines.

Instrumentation and Controls: The turbines are equipped with a distributed digital control system with a redundant data highway. The station operator consoles provide interactive color graphic displays of the overall plant, with sufficient detail to enable the operator to conveniently operate the plant.⁸ All main components of the combined-cycle plant have individual control panels and interfaces that relay information and instructions to and from the plant operator through data highways to the operator console. The operator console will have a graphic display with a high level of detail that enables convenient and informative interaction with the plant as required.⁸

These sophisticated instrumentation and controls provide a high degree of automation which results in optimal operations. The automation includes maintaining systems such as fuel feed and burner operations at optimal efficiency at all times.

Heat Recovery Steam Generator (HRSG) Energy Efficiency

The configuration includes three-pressure reheat, non-fired HRSGs. The exhaust gases from the CTGs are routed to the HRSGs. These exhaust gases are used in the Low Pressure (LP), Intermediate Pressure (IP) and High Pressure (HP) sections of the HRSG to heat water. The LP section of the HRSG produces steam to be admitted to the IP and HP sections of the Steam Turbine Generator (STG). The flue gases from the HRSG will be directed to a Selective Catalytic Reduction (SCR) system for NO_x control.

Heat Exchanger Design: The HRSG sections are made up of fine-tubed heat transfer surfaces. These surfaces are equipped with fins to provide larger contact surface area to optimize heat transfer. The HRSG takes condensate from the condensate pumps and heats it in the low pressure section of the HRSG using the exhaust gas from the CTG. The LP section of the HRSG provides preheating steam to the integral deaerator and hot water for boiler feed pump suction. The IP and HP section of the HRSG takes boiler feed pump discharge and heats feedwater to provide hot water for fuel gas performance heating (IP section) and produces IP and HP steam for introduction to the steam turbine. Saturated HP steam travels through the HP superheater section of the HRSG where heat is added to provide a final superheated HP steam which is admitted to the HP section of the steam turbine. After the expansion of the steam through the HP turbine, it is returned to the HRSG as cold reheat steam to the HRSG where it mixes with IP steam. After mixing, the cold reheat steam travels through the reheat superheater gathering heat and is admitted to the IP turbine of the STG as hot reheat steam.

The HRSGs will be equipped with exhaust gas bypass systems and flexible tube support to enable fast startup and shutdown and flexibility of operation. Reduced startup and shutdown time decreases the overall emissions from the turbines during startup/shutdown. Efficient HRSG design enables low gas-side pressure drop facilitating optimum gas turbine performance.⁸ The

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HRSG has three pressure sections for heating water to provide steam to the HP, IP, and LP sections of the turbine.

Selective Catalytic Reduction Units (SCR): The HRSGs will be equipped with SCRs to mitigate NO_x emissions. The SCR system uses ammonia to convert nitrogen oxides (NO_x) to diatomic nitrogen (N₂) thus reducing NO_x emissions.

Insulation: The key aspects of optimum utilization of heat energy from the exhaust gases is efficient transfer of heat which includes maximum contact surface area and minimal wastage of heat from surfaces that are not in contact with water/steam. This is achieved by utilization of fins and by use effective insulation. The HRSG housing and panels are well insulated to prevent loss of heat to the surroundings. This increases the efficiency of the HRSG and provides more heat towards steam generation.

Fouling Reduction: Fouling occurs on the HRSG components coming in contact with the exhaust gases due to deposition of constituents of the exhaust gases. Fouling of the surfaces reduces area of contact and impedes efficient heat transfer towards steam generation. Fouling of HRSG surfaces is restricted by filtering the inlet air to the CTGs and periodic cleaning of the affected surfaces. Scheduled maintenance will be done to maintain efficiency of the HRSG units.

Steam Wastage Reduction: Loss of generated steam is a crucial aspect in maintaining the efficiency of the HRSGs and the STGs. Loss of steam occurs from venting operations crucial to the system and leaks in the piping/equipment used to handle generated steam. Maximum retention of steam for power generation can be achieved by restricting the venting outlets, and identifying and repairing any leaks in the piping/equipment handling generated steam. Overall efficiency of the plant will be maintained by implementing procedures to identify steam leaks.

Steam Turbine Generator (STG) Energy Efficiency

CPA is proposing use of the existing Westinghouse Electric Corporation 235 MW steam turbine generator. The STG is a two-cylinder, tandem-compound, double-flow, condensing reheat unit. The high pressure turbine is of the combination impulse and reaction type. The low pressure turbine is a reaction, double flow turbine with steam entering at the center of the blade path and flowing toward an exhaust opening at each end.

Reheat Cycles: The steam turbine output depends on the nature of the steam entering the turbine. In order to maximize efficiency of the turbine and to ensure high steam temperature and pressure, reheat cycles are employed. The high pressure and intermediate pressure sections of this STG are carried in the high pressure turbine outer casing. Steam passes through the high pressure turbine blading and exits the high pressure turbine through two exhaust openings in the outer casing base as cold reheat steam where it is returned to the reheat section of the boiler. It returns from the reheater to the intermediate pressure turbine through the split intermediate pressure blading (part being located on each end of the HP – IP turbine rotor) and passes into the low pressure turbine through two cross-over pipes. This ensures optimum steam temperature and pressure conditions.

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Exhaust Steam Condenser: The spent steam from the STG is reclaimed in condensing units. CPA is proposing the use of existing Westinghouse single pass, horizontal, deaerating, rectangular condenser with divided water box. Condensing the spent steam to a saturated state reduces exhaust pressure increasing the overall turbine efficiency.

Steam Turbine Generator Design: Efficient design of the generators contributes to the overall efficiency of the system. CPA is proposing the use of an existing Westinghouse hydrogen inner-cooled generator to be used in the combined cycle generation configuration. Hydrogen cooling employed in the existing generator facilitates high-efficiency of the generator, increasing the overall efficiency of the steam turbine.

Auxiliary Energy Efficiency Processes

Fuel Gas Preheating: Turbine performance is typically increased with the use of fuel gas at a high inlet temperature. Fuel to be introduced in the turbine will be preheated through a shell and tube “performance heater” utilizing heated IP feedwater.

Multiple Trains: Multiple combustion turbines and HRSG trains offer flexibility during partial load operations. It also facilitates shutting down of operating turbines in a manner which maintains the turbine-HRSG configuration at optimum operating conditions.

Continuous Emission Monitoring System (CEMS): The CEMS unit monitors and records data on effluents from the HRSG stacks. Employing CEMS to monitor performance of the turbines provides data to optimize operations of the turbines and to keep track of the emissions from the turbines.

Operating Procedures and Practices: Vendor specified operating procedures and practices will be used to ensure efficient operation of the equipment. Implementing Standard Operating Procedures (SOPs) formulated with guidance from vendor specified operating manuals and maintenance standards will be used to ensure proper maintenance of equipment and promote efficient operation. Maintaining records of operations and practices, employing trained and certified personnel for operation and maintenance, and scheduled periodic inspections will be used to ensure equipment efficiency, longevity, and safety.

Post Combustion Controls

In addition to the combustion options discussed above, other add-on technologies to control GHG emissions are considered in this review. One such method is Carbon Capture and Storage/Sequestration (i.e., CCS). This method involves CO₂ capture, transport, and storage.

Carbon Capture: This method involves capturing post combustion effluent gas and separating carbon dioxide (CO₂) from the effluent stream. CO₂ capture using amine absorption is the only state-of-the-art CO₂ capture technology currently available. This technology has been employed in some coal-fired power plants; the following is a brief summary of the currently operating CO₂

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capture systems obtained from the *Report of the Interagency Task Force on Carbon Capture and Storage*.¹¹

1. AES's coal-fired Warrior Run (Cumberland, Maryland) and Shady Point (Panama, Oklahoma) power plants are equipped with amine scrubbers developed by ABB/Lummus. They were designed to process a relatively small percentage of each plant's flue gas. At Warrior Run, approximately 110,000 tonnes of CO₂ per year are captured, whereas at Shady Point 66,000 tonnes of CO₂ per year are captured. The CO₂ from both plants is subsequently used in the food processing industry (Dooley et al., 2009).
2. At the Searles Valley Minerals soda ash plant in Trona, California, approximately 270,000 tonnes of CO₂ per year are captured from the flue gas of a coal power plant via amine scrubbing and used for the carbonation of brine in the process of producing soda ash (IEA, 2009a; SourceWatch, 2009).
3. In September 2009, American Electric Power Co. (AEP) began operating the Alstom post combustion chilled ammonia pilot process to capture 100,000 tonnes of CO₂ per year on the Mountaineer Plant in New Haven, West Virginia, and store it in deep geologic formations beneath the Mountaineer site.
4. A pre-combustion Rectisol® system is used for CO₂ capture at the Dakota Gasification Company's synthetic natural gas (SNG) production plant located in North Dakota, which is designed to remove approximately 1.6 million tonnes of CO₂ per year from the synthesis gas. The CO₂ is purified, transported via a 200-mile pipeline, and injected into the Weyburn oilfield in Saskatchewan, Canada. However, this experience is based on a gasification plant, not an IGCC power plant (Dakota Gasification Company, Undated).

CO₂ Transport and Storage: CO₂ capture has not been demonstrated on a commercially viable scale for a full size power plant; and therefore is not a viable option to be considered as BACT. However, CPA has included a discussion in this report evaluating the transport options for the captured CO₂. The two options for transporting the captured CO₂ are:

- Transport of captured CO₂ to an existing pipeline; or
- Transport of captured CO₂ to the nearest sequestration site with proven potential to store CO₂.

There are several sites with recognized potential for use of CO₂ in Enhanced Oil Recovery (EOR) in Texas (refer to "Map of CO₂ EOR Miscible Potential in the Gulf Coast"¹² – included in this document as Attachment A) and the closest site with some demonstrated capacity for

¹¹ *Report of the Interagency Task Force on Carbon Capture and Storage*, CCS Task Force, August 2010, p.31 found at: <http://www.epa.gov/climatechange/downloads/CCS-Task-Force-Report-2010.pdf> (last accessed on June 7, 2012)

¹² Holtz, M. H., Núñez-López, V., and Breton, C. L., 2005, *Moving Permian Basin Technology to the Gulf Coast: The Geologic Distribution of CO₂ EOR Potential in Gulf Coast Reservoirs*, in Luftholm, Peter, and Cox, Denise, eds., *Unconventional reservoirs technology and strategies: alternative perspectives for the Permian Basin: West Texas Geological Society Fall Symposium*, October 26–27, Publication #05-115, CD-ROM [10 p.]. GCCC Digital Publication Series #05-02.

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geological storage of CO₂ (i.e. SACROC site in Scurry County) is over 380 miles from the proposed site.

Step 2: Eliminate technically infeasible options

In this section, CPA evaluates the technically feasible options from the technology options covered in Step 1. Specifically, this section will be addressing the feasibility of post combustion control technology (i.e., CCS) for its suitability for use with the proposed project.

Carbon Capture: Although carbon capture has been demonstrated on a smaller scale compared to the power plant applications, power plant exhausts have larger volumes and lower CO₂ concentrations (3-4% volume percent in gas-fired turbines). Carbon separation also possesses additional problems like rapid degradation of sorbents due to trace impurities in exhaust gases, increased energy demand for compressing the captured CO₂ to a pressure rating which facilitates pipeline transport.

The inter-agency task force set up by the Obama administration and co-chaired by the U.S. Department of Energy (DOE) and EPA has come to the following conclusion in the report published in August 2010:

“Current technologies could be used to capture CO₂ 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 CO₂ 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.”¹³

Additionally, the energy requirement for the carbon capture process will result in significant energy penalty (up to 30%).¹⁴ This reduces the overall efficiency of the plant and requires burning of additional fuel to meet the gap, thus contributing additional GHGs.

Due to these shortcomings, carbon capture cannot be considered as a technically feasible option as GHG BACT.

CO₂ Transport: Although there are several EOR sites available in the Gulf Coast Region, none of the sites have a demonstrated potential to store CO₂ in large quantities for prolonged time periods that will be produced from the power plant. The closest site being tested for its suitability to sequestration and to demonstrate its capacity is the Southwest Regional Partnership on Carbon Sequestration's (SWP) SACROC test site located in Scurry County. This site is approximately 380 miles from the proposed project site. A long pipeline would have to be constructed to transport the captured CO₂. Additionally, the CO₂ will need to be compressed prior to transport

¹³ Report of the Interagency Task Force on Carbon Capture and Storage, CCS Task Force, August 2010, p.50 found at <http://www.epa.gov/climatechange/downloads/CCS-Task-Force-Report-2010.pdf> (last accessed June 7, 2012).

¹⁴ U.S. Department of Energy document, *Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas Electricity*, Revision 2, November 2010, DOW/NETL-2010/1397.

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which will increase the energy demand of the power plant and decrease its efficiency. Therefore, this option is not feasible for application as GHG BACT.

CO₂ Storage: As discussed previously, CO₂ capture and transport are not currently feasible alternatives as BACT for GHG. Still even if it could be assumed that capture and transport is economically feasible, storage of CO₂ in geological structures poses additional uncertainties and requires further study/assessment before large scale deployment.

Due to the reasons discussed above, CCS technology cannot be considered as a feasible option for GHG BACT. However, to demonstrate economic infeasibility of the hypothetical CCS technology, a cost analysis has been included below.

	Combined Cycle without CCS	Combined Cycle with CCS
Total Capital Cost (2007\$/kW) ¹⁴	771	1,614
Total Capital Cost (2012\$/kW) ⁽¹⁾	867	1,814
Gross Power Output ⁽¹⁾ (kW)	911,220	824,567
Total Capital Cost (\$)	790,027,740	1,495,764,538
Cost of Electricity (2007\$/MWh) ^{14 (3)}	58.9	85.9
Cost of Electricity (2012\$/MWh) ⁽¹⁾	66.2	96.6
Cost of CO ₂ Removal (2012\$/MWh)	-	30.4
Total CO ₂ Emissions (Short-tons per year)	2,851,777	285,177
Total CO ₂ captured (Short-tons per year)	0	2,566,600
Cost of CO ₂ Removal (\$/ton of CO ₂)	--	85.55

Notes: (1) Monthly data from the Consumer Price Index (CPI) is used to convert May 2007 dollars (CPI = 204.949) to August 2012 dollars (CPI = 230.379).

(2) Gross Power Output is based on an operating temperature of 59 °F. Combined cycle with CCS gross output has been adjusted based on numbers represented in the U.S. DOE document [Reference 14].

(3) The cost of electricity is inclusive of capital costs, fuel costs, variable costs, fixed costs and CO₂ capture, transport, storage and monitoring costs

As described in the table above, the cost of implementing CCS at the ES Joslin Power Station is \$85.55/ton of CO₂ removed. Therefore, CPA considers CCS to be technologically and economically infeasible and has eliminated CCS technology from further consideration. All other technologies discussed in this review are considered feasible and CPA intends to employ these methods as BACT.

Step 3: Rank Remaining Control Technologies

CPA intends to employ all technically feasible control technologies at the proposed power plant. Therefore, ranking of the remaining control technologies is not required.

Step 4: Evaluate Most Effective Control and Document Results

Since CPA intends to employ all technically feasible control technologies at the proposed plant, evaluation of the most effective control technology is not required.

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Step 5: Select BACT

CPA is proposing the use of the following control technologies/ operating practices as BACT to mitigate GHG emissions:

- Use of Combined Cycle Power Generation
- CTG Energy Efficiency
 - Efficient compressor design
 - Efficient combustor design
 - Efficient turbine design
 - Evaporative Cooling
 - High thermal efficiency
 - Modern instrumentation, automation, and controls
 - Steam turbine bypass
- HRSG Energy Efficiency
 - Efficient heat exchanger design
 - Use of SCR to control NO_x emissions
 - Insulation to maintain efficient heat transfer
 - Prevent steam wastage
- STG Energy Efficiency
 - Use of Reheat Cycles
 - Use of exhaust steam condenser
 - Hydrogen cooling for the generator
- Auxiliary Energy Efficiency Processes
 - Fuel Gas Preheating
 - Use of multiple turbine-HRSG configurations
 - Use of CEMS
 - Efficient operating procedures
 - Personnel training

CPA proposes an output based efficiency limit of seven thousand seven hundred and thirty (7,730) British Thermal Units per Kilowatt-hour (Btu/kWh) on a net plant power output basis as BACT for GHG emissions. The proposed emission rate for the CPA Joslin Power Station for three combustion turbine generators without duct firing and one steam generator is 0.37 short-tons of CO₂/MWh or 740 lb of CO₂/MWh on a net electrical output basis. This emission rate is lower than the 1,000 lb of CO₂/MWh proposed by EPA in the New Source Performance Standards (NSPS), Subpart TTTT.

For a given output of the plant, the GHG emissions from turbines are directly proportional to the efficiency of the plant. Therefore, a decrease in efficiency will result in higher GHG emissions. In order to maintain optimum operating conditions to reduce GHG emissions, CPA is proposing an efficiency based limitation instead of a heat input based limitation. The proposed plant heat

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input rate will meet the proposed efficiency based emission limit; hence, a separate heat input based emission limit is not proposed for the project.

BACT for Emergency Engines

CPA is proposing two diesel fired emergency generators and one diesel fired fire water pump engine for emergency purposes. These engines will be fired once a month for testing purposes and the operation time will be limited to 50 hours per year. A review of the EPA alternative control technology (ACT) suggests that add-on controls such as SCR and combustion control techniques like ignition retard to control NO_x are not cost effective for emergency diesel engines as they are expected to operate only fifty (50) hours annually. CPA is proposing good combustion practices and the use of low sulfur diesel as BACT for the emergency diesel equipment.

BACT for Plant Wide Natural Gas Fugitives (Piping Equipment Fugitives)

Methane (CH₄) fugitive emissions occur from piping equipment carrying natural gas at the site. CH₄ emissions are calculated using Facility/Compound Specific Fugitive Emission Factors - Oil & Gas Production Operations in TCEQ's Air Permit Guidance for Chemical Sources: Equipment Leak Fugitives. The emission factors include Audio/Visual/Olfactory (AVO) control credits; therefore, CPA is proposing the use of AVO program to control fugitive emissions from the natural gas piping equipment. Even though the emissions are calculated based on AVO factors, CPA will be employing the more stringent Leak Detection And Repair (LDAR) program such as 28VHP.

BACT for Circuit Breakers

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. A sulfur hexafluoride (SF₆) circuit breaker uses contacts surrounded by SF₆ gas to quench the arc. Potential sources of SF₆ emissions include equipment leaks from SF₆ containing equipment, releases from gas cylinders used for equipment maintenance and repair operations, and SF₆ handling operations.

Step 1: Identify all available control technologies

The following available control technologies have been identified for the use of SF₆ as a circuit breaker:

1. Using gas-tight circuit breakers which require less amount of SF₆;
2. Implementing a Leak Detection and Repair (LDAR) program, repair leaks and repair/replace leaking equipment as quickly as possible; and
3. Training employees in proper handling and maintenance of equipment having potential emissions of SF₆.

Additionally, use of alternative substances to SF₆ (e.g., oil) has been evaluated in this review.

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Step 2: Eliminate Technically Infeasible Options

SF₆ is a superior dielectric gas for nearly all high voltage applications. It is easy to use, exhibits exceptional insulation and arc-interruption properties, and has proven its performance by many years of use and investigation.¹⁵

There are a number of disadvantages of using oil for applications in circuit breakers. The key disadvantages are flammability and high maintenance cost. Therefore, SF₆ is a technically superior alternative to oil.

Also, according to a report published by EPA,

“No clear alternative exists for this gas that is used extensively in circuit breakers, gas-insulated substations, and switch gear, due to its inertness and dielectric properties”¹⁶

Therefore, use of SF₆ in circuit breakers is the only available technically feasible option. Since SF₆ is the best available technology option for circuit breakers of SF₆, alternative substitutes will not be implemented. All other control technologies identified are feasible and will be implemented to reduce SF₆ fugitive emissions.

Step 3: Rank Remaining Control Technologies

Since all the identified technically feasible options will be employed to reduce fugitive SF₆ emissions, ranking of control technologies is not required.

Step 4: Evaluate Most Effective Controls and Document Results

All technically feasible control options will be implemented to reduce fugitive SF₆ emissions.

Step 5: Select BACT

Based on the top down analysis, CPA proposes following BACT for circuit breakers using SF₆ as the quenching media:

1. Using gas-tight circuit breakers which require less amount of SF₆;
2. Implementing a Leak Detection and Repair (LDAR) program, repair leaks and repair/replace leaking equipment as quickly as possible; and
3. Training employees in proper handling and maintenance of equipment having potential emissions of SF₆.

¹⁵ Christophorous, L.G., Olthoff, J.K., and Green, D.S., *Gases for Electrical Insulation and Arc Interruption: Possible Present and Future Alternatives to Pure SF₆*, NIST Technical Note 1425, November 1997.

¹⁶ *SF₆ Emission Reduction Partnership for Electric Power Systems 2007 Annual Report*, U.S. Environmental Protection Agency, December 2008, available at: http://www.epa.gov/electricpower-f6/documents/sf6_2007_ann_report.pdf (last accessed on June 7, 2012)