REGIONAL HAZE FOUR-FACTOR ANALYSIS

Harvest Four Corners, LLC
Kutz Canyon Processing Plant

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1. EXECUTIVE SUMMARY

In the 1977 amendments to the Clean Air Act (CAA), Congress set a nation-wide goal to restore national parks and wilderness areas to natural conditions by remedying existing, anthropogenic visibility impairment and preventing future impairments. On July 1, 1999, the U.S. Environmental Protection Agency (EPA) published the final Regional Haze Rule (RHR). The objective of the RHR is to restore visibility to natural conditions in 156 specific areas across the United States, known as Federal Class I areas. The CAA defines Class I areas as certain national parks (over 6,000 acres), wilderness areas (over 5,000 acres), national memorial parks (over 5,000 acres), and international parks that were in existence on August 7, 1977.

The RHR requires states to set goals that provide for reasonable progress towards achieving natural visibility conditions for each Class I area in their jurisdiction. In establishing a reasonable progress goal for a Class I area, each state must:

> *(A) Consider the costs of compliance, the time necessary for compliance, the energy and non-air quality environmental impacts of compliance, and the remaining useful life of any potentially affected sources, and include a demonstration showing how these factors were taken into consideration in selecting the goal. 40 CFR 51. 308(d)(1)(i)(A).*
>
> This is known as a four-factor analysis.
>
> *(B) Analyze and determine the rate of progress needed to attain natural visibility conditions by the year 2064. To calculate this rate of progress, the State must compare baseline visibility conditions to natural visibility conditions in the mandatory Federal Class I area and determine the uniform rate of visibility improvement (measured in deciviews) that would need to be maintained during each implementation period in order to attain natural visibility conditions by 2064. In establishing the reasonable progress goal, the State must consider the uniform rate of improvement in visibility and the emission reduction. 40 CFR 51. 308(d)(1)(i)(B).*
>
> The uniform rate of progress or improvement is sometimes referred to as the glidepath and is part of the state's Long-Term Strategy (LTS).

The second implementation planning period (2018-2028) for national regional haze efforts is currently underway. There are a few key distinctions from the processes that took place during the first planning period (2004-2018). Most notably, the second planning period analysis distinguishes between natural or biogenic and manmade or anthropogenic sources of emissions. Using a Photochemical Grid Model (PGM), the Western Region Air Partnership (WRAP), in coordination with the EPA, is tasked with comparing anthropogenic source contributions against natural background concentrations.

Pursuant to 40 CFR 51.308(d)(3)(iv), the states are responsible for identifying the sources that contribute to the most impaired days in the Class I areas. To accomplish this, the New Mexico Environment Department (NMED) reviewed 2016 emission inventory data for major sources and assessed each facility's impact on visibility in Class I areas with a "Q/d" analysis, where "Q" is the magnitude of emissions that impact ambient visibility and "d" is the distance of a facility to a Class I area. From this analysis, 24 facilities were identified by the NMED. On July 18, 2019 the NMED informed Harvest Four Corners, LLC (Harvest) that its Kutz Canyon Processing Plant (Kutz) facility was identified as one of the sources potentially contributing to regional haze at the Mesa Verde National Park Class I area.

In coordination with WRAP, the NMED devised criteria to determine specific equipment that is subject to the four-factor analysis. In the NMED's July 18, 2019 notification letter to Harvest, it specifies that any equipment with a potential to emit (PTE) greater than 10 pounds per hour (lb/hr) and 5 tons per year (tpy) of Nitrogen Oxides (NO_X) or Sulfur Dioxide (SO_2) shall be included in this analysis. The subject equipment at Kutz, the PTE associated with that equipment, and the applicability of a four-factor analysis for each pollutant are reported in Table 1.

Table 1. Summary of Equipment and Applicability to a Four-Factor Analysis

Equipment	NO_X Hourly PTE (lb/hr)	NO_X Annual PTE (tpy)	NO_X Subject to Analysis? (Yes/No)	SO_2 Hourly PTE (lb/hr)	SO_2 Annual PTE (tpy)	SO_2 Subject to Analysis? (Yes/No)
Natural Gas-Fired Simple Cycle Turbine (Unit 1)	15.5	67.9	Yes	0.029	0.13	No
Natural Gas-Fired Simple Cycle Turbine (Unit 2)	15.5	67.9	Yes	0.029	0.13	No
Natural Gas-Fired Simple Cycle Turbine (Unit 3)	15.5	67.9	Yes	0.029	0.13	No
Natural Gas-Fired Simple Cycle Turbine (Unit 4)	15.5	67.9	Yes	0.029	0.13	No
Natural Gas-Fired Simple Cycle Turbine (Unit 5)	15.5	67.9	Yes	0.029	0.13	No
Natural Gas-Fired Simple Cycle Turbine (Unit 6)	15.5	67.9	Yes	0.029	0.13	No
Natural Gas-Fired Simple Cycle Turbine (Unit 19)	15.5	67.9	Yes	0.029	0.13	No
Natural Gas-Fired Simple Cycle Turbine (Unit 20)	15.5	67.9	Yes	0.029	0.13	No
Clark HRA-8 Reciprocating Compressor Engine (Unit 16)	37.1	162.0	Yes	0.007	0.031	No
Clark HRA-8 Reciprocating Compressor Engine (Unit 17)	37.1	162.0	Yes	0.007	0.031	No
Clark HRA-8 Reciprocating Compressor Engine (Unit 18)	37.1	162.0	Yes	0.007	0.031	No

Once the applicability of equipment and pollutants has been determined, potential retrofit control technologies must be identified. In accordance with 40 CFR 51 Appendix Y and at the recommendation of the NMED[1], this is primarily achieved by utilizing the Reasonably Available Control Technology (RACT) / Best Available Control Technology (BACT) / Lowest Achievable Emission Reduction (LAER) Clearinghouse (RBLC) data. In order to determine the most relevant and current retrofit controls available, the RBLC is queried for the previous ten years. Summaries of the result of this search are provided and discussed under Section 2 of this report. Harvest engineers then reviewed the list of available retrofit technologies and performed a technical feasibility assessment for each control option. The four-factor analysis is then conducted for those controls that are technically feasible.

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[1] NMED 2021 Regional Haze Planning Website ("Links to other information"). https://www.env.nm.gov/air-quality/reg-haze/

2. BACKGROUND INFORMATION & TECHNICAL FEASIBILITY

NO_X is the only pollutant subject to evaluation in this four-factor analysis for the eight (8) turbines and three (3) engines located at Kutz. The turbines, Unit 1 through Unit 6, are Solar model Centaur 40-T4002 natural gas-fired, simple cycle turbines. Turbine Unit 19 and Unit 20 are Solar model Centaur 40-T4001 natural gas-fired, simple cycle turbines. The engines, Units 16, 17, and 18, are Clark model HRA-8 natural gas-fired, two-stroke lean-burn (2SLB) reciprocating compressor engines.

Units 1 through 6 are rated at 3,830 horsepower and were manufactured in 1975. Units 19 and 20 are rated at 3,016 horsepower and were manufactured in 1981. The engines are each rated at 830 horsepower and were manufactured prior to 1973. The units are de-rated in the 2016 Emission Inventory submittal to account for the altitude of the facility. Units 1 through 6 are rated at 3,692 hp, Units 19 and 20 at 2,907 hp, and Units 16 through 18 at 723 hp.

2.1. COMBUSTION TURBINES

2.1.1. Combustion Turbine Background

A gas turbine is an internal combustion engine that operates with a rotary, rather than reciprocating, motion and is composed of three primary components: a compressor, a combustor, and a power turbine. The compressor draws in ambient air and compresses it up to 30 times the ambient pressure, then directs it into the combustor where fuel is introduced, ignited, and burned. Exhaust gas from the combustor is then diluted with additional air and sent to the power turbine at temperatures up to 2600 °F. The hot exhaust gas expands in the power turbine section, generating energy in the form of shaft horsepower.[2]

The treatment of the exhaust gases exiting the turbine dictate the cycle designation of these units. The heat content can either be discarded without heat recovery (simple cycle); recovered with a heat exchanger to preheat combustion air entering the combustor (regenerative cycle); recovered in a heat recovery steam generator to raise process steam, with or without supplementary firing (cogeneration); or recovered, with or without supplementary firing, to raise steam for a steam turbine Rankine cycle (combined cycle or repowering).[3] The units at Kutz are simple cycle turbines.

NO_X is formed via three fundamentally different mechanisms. The principle NO_X formation mechanism, thermal NO_X, arises from the thermal dissociation and subsequent reaction of nitrogen (N_2) and oxygen (O_2) molecules during combustion. Most thermal NO_X forms in the highest temperature regions of the combustion chamber. The second NO_X formation mechanism, fuel NO_X, arises from the evolution and reaction of fuel bound nitrogen compounds with oxygen. The final NO_X formation mechanism, prompt NO_X, arises from early reactions of nitrogen intermediaries and hydrocarbon radicals in fuel.

The significance of prompt NO_X is negligible in comparison to thermal and fuel NO_X. Fuel NO_X will also be negligible for Kutz’s turbines assessed here, as these combustion turbines fire natural gas, which contains a negligible amount of nitrogen compounds. Therefore, this analysis will focus on thermal NO_X.

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[2] U.S. EPA, AP-42, Section 3.1, "Stationary Gas Turbines"
[3] Ibid.

The PTE from each turbine is reported in the facility's New Source Review (0301M11) and Title V (P097R3) permits, as well as summarized in Table 1 of this report.

2.1.2. Potential NO_X Controls for Combustion Turbines

There are three general methods of controlling NO_X emission from gas turbines: (1) wet controls, which use steam or water injection to reduce combustion temperatures and NO_X formation; (2) dry controls that use advanced combustor design to suppress NO_X formation; and (3) post-combustion, catalytic controls to selectively reduce NO_X.[4]

The retrofit control equipment that was identified for combustion turbines during a comprehensive review of the RBLC, available literature, and manufacturer's input is reported in Table 2. A more detailed table summarizing the RBLC review is provided in Appendix A. A detailed discussion, including a description, the technical feasibility, and the anticipated performance of each control is provided below.

Table 2. Potential Control Options for Combustion Turbines

Control Equipment	Technically Feasible?	NO_X Control Efficiency
Good Combustion Practices	Yes	Base Case
Improved Combustion Technology	Yes	63%
Water/Steam Injection	No	N/A
Selective Catalytic Reduction	No	N/A

2.1.2.1. Good Combustion Practices

NO_X emissions are caused by oxidation of nitrogen gas in the combustion air during fuel combustion. This occurs due to high combustion temperatures and insufficiently mixed air and fuel in the cylinder where pockets of excess oxygen occur. By following concepts from engineering knowledge, experience, and manufacturer's recommendations, good combustion practices for operation of the units can be developed and maintained by training maintenance personnel on equipment maintenance, routinely scheduling inspections, conducting overhauls as appropriate for equipment involved, and using pipeline quality natural gas. By maintaining good combustion practices, the unit will operate as intended with the lowest NO_X emissions.

Utilizing good combustion practices and fuel selection was identified in this review of the RBLC for the control of NO_X emissions from combustion turbines; therefore, it has been determined that this method of NO_X control is feasible for the units at Kutz. However, these practices have been developed for and are currently in use at Kutz, as required by various conditions in its Title V and NSR permit authorizations. No further assessment of these control practices is included in this report.

2.1.2.2. Improved Combustion Technology

The improved combustion technology control option, commonly referred to as Dry Low NO_X (DLN) control, seeks to reduce the combustion temperature and residence time of fuel in the combustor (thereby decreasing NO_X formation) by increasing the air-to-fuel ratio in the combustion chamber. There are several levels of

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[4] Ibid.

improvements that can be made to the combustion chamber, which achieve this NO_X control at varying levels. The improved combustion technology available for the units at Kutz is produced by the manufacturer of the units, Solar, and is called $SoLoNO_X$. $SoLoNO_X$ utilizes lean-premixed combustion technology to ensure an extremely uniform air/fuel mixture and stringently controls the combustion process to prevent undesirable emissions from forming.

Based on communication with Solar, $SoLoNO_X$ is available for both the T4001 (Units 19 and 20) and T4002 (Units 1 through 6) Solar turbines located onsite. However, in order to support the technology each of the units would need to be uprated to model T4701 and T4702, respectively, because installation of $SoLoNO_X$ requires the turbine combustors to be capable of handling significantly higher temperatures. Uprating the units involves completely replacing the combustor section of the turbine with a much larger and more robust combustor.

Improved combustion technology, such as $SoLoNO_X$, was identified in this review of RBLC as a potential control of NO_X emissions from natural gas-fired combustion turbines, and AP-42 Section 3.1 also lists this as an available control technique for gas turbines.[5] Therefore, it has been determined that this control technology is technically feasible for the turbines located at Kutz. Solar can guarantee an output NO_X concentration of 25 parts per million (ppm) for uprated units with $SoLoNO_X$ installed. This is a resulting NO_X emissions reduction of approximately 63%, based on the currently permitted hourly emission rate and turbine stack parameters.

2.1.2.3. Water/Steam Injection

Water injection is a control technology for gas turbines that has been demonstrated to effectively suppress NO_X emissions. Injection of water has the effect of increasing the thermal mass by dilution and thereby reducing the peak temperature in the flame zone. Additionally, the latent heat of vaporization from the flame zone is absorbed when water injection is utilized, further reducing the combustion temperature. Water is typically injected at a water-to-fuel weight ratio of less than one.[6] Steam injection is not discussed as an option because Solar does not manufacture turbines with steam injection technology.

The capability of these units to be retrofit for water injection is dependent on the number of shafts employed in the unit, per communications with Solar. The shaft is the piece of equipment in the unit that connects the turbine to the generator and turns to generate the power output. Solar has indicated that turbine units with one shaft are mechanically capable of installing water injection, while two-shaft units are not. The Solar T4002 turbines (Units 1 through 6) located at Kutz are two-shaft units and the Solar T4001 turbines (Units 19 & 20) are one-shaft units. Therefore, the model T4002 turbines are not mechanically capable of being retrofit for water injection, while the model T4001 turbines are.

Despite the Solar T4001 units being mechanically capable of supporting water injection, Solar has stated that they do not offer water injection retrofits for any of the Centaur 40 conventional combustion line of turbines. This is primarily due to the design of the combustor housing of the conventional Centaur 40. The injectors on this style of combustor intersect directly into the combustor without using direct air flow for the direction of fuel. The style of injector needed to implement water injection technology is referred to by Solar as a Dual Lined Injector. This type of injector introduces fuel laterally into the front of a combustor and utilizes a controlled flow to disperse fuel.

Solar considers the control technique to be antiquated technology in comparison to the other control methods they have available, such as $SoLoNO_X$. Solar has retired this control option and does not recommend water

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[5] Ibid.

[6] Ibid.

injection be installed to control emissions from their turbine units. They have stated that if there were direct modifications made to the turbine engine or it's supporting hardware, it could affect the unit's warranty with Solar.

Furthermore, approximately 5 gallons per minute (gpm) of de-ionized or de-mineralized water is needed to properly implement this control, per conversations with Solar. For a continuously operating turbine, this represents a total water usage of approximately 2.6 million gallons per year, per unit, without taking into account leaks and evaporative losses that would occur during transport. Kutz is located in San Juan County, in the northwestern part of the state. The National Drought Mitigation Center currently classifies this region as experiencing severe drought conditions.[7] The New Mexico Office of the State Engineer projects that the water demand in the San Juan region will exceed the drought-adjusted available water supply before 2030.[8] The implementation of this control may pose an unsustainable burden on this region's watershed.

Based on the communication with the turbine manufacturer detailed above, as well as the lack of available water in the region, it has been determined that water and steam injection are technically infeasible for the Solar turbines located at Kutz.

2.1.2.4. Selective Catalytic Reduction Systems

Selective Catalytic Reduction (SCR) is the process by which a nitrogen-based reagent, such as ammonia or urea, is injected into the exhaust of a combustion unit. Within a reactor vessel containing a metallic or ceramic catalyst, the injected reagent reacts selectively with the NO_X in the exhaust to produce molecular nitrogen (N_2) and water (H_2O).[9] The chemical reactions for this process are shown in the equations below.

$$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$$

$$2\ NO_2 + 4\ NH_3 + O_2 \rightarrow 3\ N_2 + 6\ H_2O$$

An SCR system includes the catalyst, catalyst housing, reagent storage tank, reagent injector, reagent pump, pressure regulator, and an electronic control system. The electronic controls regulate the quantity of reagent injected as a function of turbine load, speed, and temperature, so NO_X emissions reductions can be achieved. The lifespan of the catalyst is primarily determined by poisoning of active sites by flue gas constituent, thermal sintering, or compacting, of active sited due to high temperatures in the reactor, fouling caused by ammonia-sulfur salts and particulate matter in the gas, and erosion due to high gas velocities.[10]

Typically, a small amount of ammonia is not consumed in the reactions and is emitted in the exhaust stream. These ammonia emissions are referred to as ammonia slip. Unreacted ammonia in the exhaust can form ammonium sulfates which may plug or corrode downstream equipment. Particulate-laden streams can blind the catalyst and may necessitate the application of a soot blower.[11]

For an SCR system to function properly, the exhaust gas must be within a particular temperature range (typically between 450 and 850 °F), dependent on the material of the catalyst. Exhaust gas temperatures greater than the

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[7] Brian Fuchs, National Drought Mitigation Center, "United States Drought Monitor – New Mexico", https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?NM

[8] State of New Mexico Interstate Stream Commission, Office of the State Engineer, "San Juan Basin Regional Water Plan 2016", Figure ES-3. Available Supply and Projected Demand.

[9] U.S. EPA, Office of Air Quality Planning and Standards, "Air Pollution Control Technology Fact Sheet (Selective Catalytic Reduction (SCR))," EPA-452/F-03-032.

[10] Ibid.

[11] Ibid.

upper limit will cause the NO_X and ammonia to pass through the catalyst unreacted.[12] The exhaust temperature of the turbines assessed here is approximately 1,271 °F. It is unlikely that SCR control would function effectively on the Solar turbines due to the high exhaust temperature of these units. In addition, there are site-specific space limitations associated with the building and stack orientations that will prevent installation of the necessary equipment for this control method (i.e., SCR module and reagent storage systems).

Furthermore, Harvest does not anticipate that the current electricity availability at Kutz will be sufficient to support the substantial energy burden associated with SCR control. Installation of this control will require the facility to expand its current power generation.

Communication with Solar has indicated that SCR controls are available for each of the turbine models assessed here. However, it is not anticipated that the exhaust temperature, space, and energy limitations can be overcome; therefore, it has been determined that SCR is not a technically feasible control option for the turbines located at Kutz.

2.2. TWO-STROKE LEAN-BURN ENGINES

2.2.1. Two-Stroke Lean-Burn Engines Background

A reciprocating internal combustion engine (RICE) is a device that uses the combustion of fuel and air in an internal chamber to generate a reciprocating motion and convert heat energy into mechanical work. The units use a piston to draw air and fuel into the combustion chamber and compress it. The compressed air/fuel mixture is then ignited, generating combustion in the chamber. The energy of combustion pushes out the piston, turning a crankshaft and producing mechanical work. In the same cycle, the products of combustion remaining in the chamber are released and exhausted from the unit.

Natural gas-fired RICE are separated into multiple design classes, including 2-stroke lean-burn (2SLB), 4-stroke lean-burn (4SLB), and 4-stroke rich-burn (4SRB). The four-stroke design uses four strokes of the piston, or two turns of the crankshaft, to complete the power cycle. The two-stroke design completes the power cycle in a single revolution of the crankshaft. Rich-burn engines are designed to operate close to the stoichiometric, or chemically balanced, air-to-fuel ratio (around 16:1) with exhaust oxygen levels less than 4%, while lean-burn engines operate at significantly higher air-to-fuel ratios (ranging from 20:1 to 50:1), with exhaust oxygen levels of 12% or more.[13]

NO_X is formed in reciprocating engines via the same three mechanisms applicable to the turbines:

(1) Thermal NO_X - the thermal dissociation and subsequent reaction of nitrogen (N_2) and oxygen (O_2) molecules during combustion,
(2) Fuel NO_X - the evolution and reaction of fuel-bound nitrogen compounds with oxygen, and
(3) Prompt NO_X - the early reactions of nitrogen intermediaries and hydrocarbon radicals in fuel.

The Kutz engines also use natural gas fuel; therefore, the formation of prompt and fuel NO_X will again be insignificant, and this analysis will focus on thermal NO_X. The rate of NO_X formation through the thermal NO_X mechanism is highly dependent upon the air-to-fuel ratio, combustion temperature, and residence time at the combustion temperature. Maximum thermal NO_X formation occurs near the stoichiometric air-to-fuel mixture ratio because combustion temperatures are greatest at this ratio.[14]

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[12] U.S. EPA, AP-42, Section 3.1, "Stationary Gas Turbines"
[13] U.S. EPA, AP-42, Section 3.2, "Natural Gas-Fired Reciprocating Engines"
[14] Ibid.

NO_X reduction in natural gas-fired RICE can be accomplished by three general methods, as follows:[15]

(1) Operational control methods, such as adjusting the timing or other operating parameters.
(2) Combustion control techniques, for example reducing the peak flame temperature or introducing inerts that limit initial NO_X formation.
(3) Post-combustion NO_X control technologies, which employ various strategies to chemically reduce NO_X.

The PTE from each engine is reported in the facility's New Source Review (0301M11) and Title V (P097R3) permits, as well as summarized in Table 1 of this report.

2.2.2. Potential NO_X Controls for 2SLB Engines

Retrofit control options identified for 2SLB RICE were identified via comprehensive review of the RBLC and available technical literature and are summarized in Table 3. A detailed description and discussion of the technical feasibility and anticipated performance of each control is provided below.

Table 3. Potential Control Equipment for 2SLB RICE

Control Equipment	Technically Feasible?	NO_X Control Efficiency
Good Combustion Practices and Fuel Selection	**Yes**	**Base Case**
Clean Burn Technology	**Yes**	**80% - 93%**
Selective Catalytic Reduction	**No**	**N/A**
Non-Selective Catalytic Reduction	**No**	**N/A**

2.2.2.1. Good Combustion Practices and Fuel Selection

By following the same concepts from engineering knowledge, experience, and manufacturer's recommendations referenced above, good combustion practices for operation of engines can be developed and maintained. This is achieved by training maintenance personnel on equipment maintenance, routinely scheduling inspections, conducting overhauls as appropriate for equipment involved, and using pipeline quality natural gas. By maintaining good combustion practices, the unit will operate as intended with the lowest NO_X emissions.

Utilizing good combustion practices and fuel selection was identified in this review of the RBLC for the control of NO_X emissions from 2SLB engines; therefore, it has been determined that this method of NO_X control is feasible for the engines at Kutz. However, these practices have been developed for and are currently in use at Kutz, as required by various conditions in its Title V and NSR permit authorizations. No further assessment of these control practices is included in this report.

2.2.2.2. Clean Burn Technology

Clean Burn Technology (CBT) is another term for utilizing combustion mixtures in engines with fuel-lean air-to-fuel ratios. This method of reducing NO_X emissions involves reconfiguring the engines by adding or enhancing an air-to-fuel ratio controller, making the unit capable of operating at more desirable ratios.

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[15] Ibid.

Rich-burn engines are normally designed to operate close to the stoichiometric, or chemically balanced, air-to-fuel ratio of 16:1, while lean-burn engines operate at significantly higher air-to-fuel ratios (ranging from 20:1 to 50:1). A combustion mixture with a higher air-to-fuel ratio results in reduced NO_X emissions, because using fuel-lean mixtures lowers the combustion temperature by diluting energy input. 2SLB engines are typically designed to operate at the high air-to-fuel ratios employed in CBT; however, further increasing the air-to-fuel ratio in lean-burn engines can decrease the NO_X emissions.[16]

In order to avoid derating the engine, combustion air must be increased at constant fuel flow. To achieve this, the engine would need to be retrofitted with a turbocharger, which forces additional air into the combustion chamber, as well as an automatic air-to-fuel ratio controller.

Many 2SLB engines, such as naturally aspirated engines, do not have identical air-to-fuel ratios in each cylinder, which can result in limited ability to vary the air-to-fuel ratio. To maintain acceptable engine performance at lean conditions, high energy ignition systems (HEIS) have been developed that promote flame stability at very lean conditions.[17]

There is limited manufacturer support available to provide input on the potential effect installation of these controls could have on the engines. As such, a third-party control vendor with significantly less unit-specific experience and familiarity would need to be employed to install this control. Harvest is concerned that the addition of this control equipment by a third-party vendor could negatively affect the units and ultimately be operationally detrimental due to their limited historical knowledge of the engines.

Despite the potential drawbacks to installation of CBT control on these units discussed above, 2SLB engines are mechanically capable of being retrofit to support the combustor modifications and more sensitive air-to-fuel ratio controllers necessary to employ CBT. Therefore, it has been determined that this method of NO_X control is feasible for the 2SLB engines at Kutz. On 2SLB RICE, CBT is estimated to achieve an 80 to 93% reduction in NO_X emissions; however, this reduction is specific to each engine and typical loading.[18]

2.2.2.3. Selective Catalytic Reduction

Implementation of SCR controls for engines follows the same process and has the same technical drawbacks as discussed in Section 2.1.2.4 of this report.

For engines that typically operate at variable loads, such as engines on gas transmission pipelines, an SCR system may not function effectively, causing either periods of ammonia slip or insufficient ammonia to gain the reductions needed.[19] Kutz does typically operate with variable loads; therefore, the facility expects to have periods of ammonia slip or insufficient ammonia.

In order for the chemical reactions necessary for SCR to occur effectively, the exhaust streams injected with the reagent must be fairly oxygen rich. The exhaust oxygen levels for 2SLB engines are sufficient to support these reactions; therefore, this technology can be used on lean-burn engines.

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[16] State of the Art (SOTA) Manual for Reciprocating Internal Combustion Engines, State of New Jersey Department of Environmental Protection, 2003.

[17] Ibid.

[18] U.S. EPA, Office of Air Quality Planning and Standards, “Alternative Control Techniques Document – NO_X Emissions from Stationary Reciprocating Internal Combustion Engines”, EPA-453/R-93-032, Section 5.2.5.4, July 1993

[19] U.S. EPA, AP-42, Section 3.2, "Natural Gas-Fired Reciprocating Engines"

AP-42 Section 3.2 does list SCR as an available control technology for 2SLB engines; however, the RBLC does not identify SCR as a control for these specific engine models.[20] This is likely because there is limited operating experience to date with the use of SCR on 2SLB RICE. Additionally, there is historical precedent that installation of SCR on 2SLB engines can result in significant technical complications, including a necessity to derate the engines and unreliable operation post-retrofit. The engines at Kutz are currently de-rated to account for the altitude of the facility. It is not operationally appropriate to de-rate the units further, as would be necessary if SCR control is implemented.

An engine control vendor contacted indicated that the Clark HRA-8 model of engines are poorly suited for installation of SCR controls and they do not typically recommend this for control due to the availability of more suitable options, such as CBT. The control vendor stated that significant challenges would need to be overcome to install this equipment on the units. Primarily, the poor air-to-fuel ratio employed in these units will make it difficult to regulate the SCR and greatly affect the NO_X reduction capability out of the engine. Additionally, a turbocharger and intercooler would need to be installed in the units to support the SCR equipment. As SCR control technology is not listed in the RBLC tables for 2SLB engines, has not been a proven as an effective method of controlling NO_X, and has significant operating challenges, Harvest has determined this control is technically infeasible for the Clark HRA-8 engines at Kutz.

2.2.2.4. Non-Selective Catalytic Reduction

Non-Selective Catalytic Reduction (NSCR) is a control technique that uses residual hydrocarbons and carbon monoxide (CO) in engine exhaust as a reducing agent for NO_X. In an NSCR system, hydrocarbons and CO are oxidized by oxygen (O_2) and NO_X. The excess hydrocarbons, CO, and NO_X pass over a catalyst (usually a noble metal such as platinum, rhodium, or palladium) that oxidizes the excess hydrocarbons and CO to H_2O and CO_2, while reducing NO_X to N_2.[21] This technique does not require additional reagents to be injected because the unburnt hydrocarbons in the engine exhaust are used as the reductant. The chemical reactions for this process are shown in the equations below.[22]

$$\text{Phase 1:} \quad \left.\begin{array}{l} 2CO + O_2 \rightarrow 2CO_2 \\ 2H_2 + O_2 \rightarrow 2H_2O \\ HC + O_2 \rightarrow CO_2 + H_2O \end{array}\right\}$$

$$\text{Phase 2:} \quad \left.\begin{array}{l} NO_X + CO \rightarrow CO_2 + N_2 \\ NO_X + H_2 \rightarrow H_2O + N_2 \\ NO_X + HC \rightarrow CO_2 + H_2O + N_2 \end{array}\right\}$$

The reactions in Phase 1 of the chemical process above function to remove excess oxygen from the exhaust stream. This step is necessary because if the oxygen is not removed, it will react more readily with the CO and hydrocarbons than the NO_X, thus reducing the potential for NO_X removal.

Despite this oxygen removal step in the chemical process, the engine exhaust gas stream must already have low levels of excess oxygen, or the oxygen will not be fully removed in Phase 1 and the NO_X removal will not be efficient. Consequently, application of the NSCR control technique is effectively limited to engines with normal exhaust

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[20] Ibid.

[21] Ibid.

[22] U.S. EPA, "Compliance Assurance Monitoring Technical Guidance Document", Appendix B Review Draft, 2005

oxygen levels of 4% or less. This does not include lean-burn engines, which typically have an exhaust excess oxygen level around 8%, ranging from 4% to 17%.[23]

The exhaust oxygen levels for 2SLB engines are not sufficiently low to support the reactions described above; therefore, this technology is not a method used to control NO_X emissions from lean-burn engines. Furthermore, NSCR was not identified in the review of the RBLC as a potential control of NO_X emissions from large natural gas-fired lean-burn stationary RICE and AP-42 Section 3.2 does not list NSCR as an available control technique for 2SLB engines.[24] For these reasons, it has been determined that this method of NO_X control is infeasible for the 2SLB engines at Kutz.

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[23] U.S. EPA, AP-42, Section 3.2, "Natural Gas-Fired Reciprocating Engines"
[24] Ibid.

Harvest has evaluated the costs of implementing the technologically feasible control technologies as thoroughly as possible in the time provided to complete this assessment. These cost estimates are calculated according to the methods and recommendations in the EPA Air Pollution Control Cost Manual.[25] Cost effectiveness considerations for each unit and control technology are discussed below.

These cost estimates have been developed based on the actual emissions from each unit assessed here, using the 2016 Emission Inventory submittal for Kutz. The full cost estimation for each unit, including the EPA Air Pollution Control Cost Spreadsheet, are included in Appendix B of this report.

3.1. COMBUSTION TURBINES

Cost effectiveness for each combustion turbine control option are summarized Table 4.

Table 4. Cost Analysis Summary of Technically Feasible Control Options for Combustion Turbines at Kutz

Control Equipment	Unit	Capital Cost ($)	Total Annual Cost ($)*	Emission Reduction (tpy)	Cost Effectiveness ($/ton)
Improved Combustion Technology	1	467,300	61,603	27.4	2,246
	2	467,300	61,603	25.5	2,412
	3	467,300	61,603	31.1	1,983
	4	667,300	78,339	3.4	23,111
	5	667,300	78,339	36.5	2,145
	6	667,300	78,339	41.0	1,910
	19	467,300	61,603	12.9	4,779
	20	467,300	61,603	30.1	2,043

*Total Annual Cost includes the annualized capital cost, as well as the direct and indirect annual operating costs.

3.1.1. Improved Combustion Technology

Harvest has received an estimated direct capital cost for the equipment and vendor labor associated with implementing SoLoNO$_X$ on the turbines located at Kutz from Solar. Solar has also provided an estimated annual cost necessary to operate and maintain the units post-retrofit.

This cost estimate assumes that SoLoNO$_X$ will reduce NO$_X$ emissions to an outlet concentration of 25 ppm, based on manufacturer's estimations.

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[25] U.S. EPA, "Air Pollution Control Cost Manual", available at: https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution#cost%20manual

3.2. 2SLB ENGINES

Cost effectiveness for each engine control option are summarized Table 5.

Table 5. Cost Analysis Summary of Technically Feasible Control Options for Engines at Kutz

Control Equipment	Unit	Capital Cost ($)	Total Annual Cost ($)*	Emission Reduction (tpy)	Cost Effectiveness ($/ton)
Clean Burn Technology	16	1,000,000	123,679	121.1	1,021
	17	1,000,000	123,679	71.7	1,725
	18	1,000,000	123,679	70.0	1,767

*Total Annual Cost includes the annualized capital cost, as well as the direct and indirect annual operating costs.

3.2.1. Clean Burn Technology

Harvest has estimated the capital cost for the equipment and labor associated with implementing CBT on the 2SLB engines located at Kutz, as well as the annual costs necessary to operate and maintain the units.

This cost estimate assumes that the CBT control will reduce NO_X emissions by 80%, per the EPA's Alternative Control Techniques document on NO_X emissions from stationary RICE.[26]

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[26] U.S. EPA, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document – NO_X Emissions from Stationary Reciprocating Internal Combustion Engines", EPA-453/R-93-032, Section 5.2.5.4, July 1993

4. TIME NECESSARY FOR COMPLIANCE

The second factor in this analysis is the time necessary for compliance. Consideration of this factor involves estimating the time required for a source to implement a potential control measure. This information is provided here in order to advise the NMED of Harvest's projection of a reasonable compliance timeline based on the equipment and site-specific considerations that could affect the time necessary to comply.

4.1. COMBUSTION TURBINES

4.1.1. Improved Combustion Technology

Harvest estimates that approximately 2-3 years will be needed to implement the improved combustion technology control equipment. Factors that have been considered for this anticipated timeline include budgeting, design, uprating the combustors, procuring the equipment, and installing the control.

4.2. 2SLB ENGINES

4.2.1. Clean Burn Technology

Harvest estimates that approximately 2-3 years will be needed to budget, design, procure, and construct the clean burn technology control equipment. For this anticipated timeline, Harvest has considered the time necessary to identify a control vendor, budget and plan the project, and order and install the equipment.

5. ENERGY AND NON-AIR ENVIRONMENTAL IMPACTS

This section addresses the potential energy and non-air environmental impacts that installation of the technically feasible control options poses on a source. The consideration of energy impacts involves assessing the impact of a control measure on the energy that is consumed by the source. Non-air environmental impacts are assessed based on the effect of the control on non-air environmental media. Some examples of non-air environmental impacts include water resource depletion, solid waste generation, increased noise and odor pollution, and increased land usage.

5.1. COMBUSTION TURBINES

5.1.1. Improved Combustion Technology

It is not anticipated that installation of the improved combustion technology (SoLoNO$_X$) on the turbines at Kutz will have any significant energy or non-air environmental impacts.

5.2. 2SLB ENGINES

5.2.1. Clean Burn Technology

Clean burn technology control employs a combustion mixture with a higher air-to-fuel ratio, because using fuel-lean mixtures lowers the combustion temperature by diluting energy input. This will reduce NO$_X$ emissions; however, a reduction in combustion temperature also tends to increase emissions of CO, due to incomplete combustion.[27]

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[27] Solar Turbines, “Developments in Dry Low Emissions Technology”, 2006

6. REMAINING USEFUL LIFE OF SOURCES

The anticipated remaining useful life of each source is addressed here for the NMED's consideration. The assessment of this factor involves estimating how long the sources analyzed will remain in operation and the lifetime of potential control measures, accounting for equipment and site-specific limitations.

40 CFR Part 51, Appendix Y includes guidance on the characterization of this factor, stating that the remaining useful life of a source will typically be longer than the useful life of the emission control system. Therefore, it is appropriate to annualize compliance costs based on the useful life of the control equipment, rather than the life of the source.[28]

6.1. COMBUSTION TURBINES

Based on their current age and operating efficiency, it is estimated that the remaining useful life of the turbines will be longer than the control units. The turbines have operated for more than 35 years without any significant deterioration in operating efficiency; therefore, this analysis of the remaining useful life of the equipment will be based on the anticipated useful life of the control device considered.

6.1.1. Improved Combustion Technology

It is anticipated that the estimated useful life of the improved combustion technology, SoLoNO$_X$, will be similar to the useful life of an SCR system. The useful life is estimated to be 20 years, based on default values from the EPA Air Pollution Control Cost Manual.[29]

6.2. 2SLB ENGINES

The 2SLB engines at Kutz have similarly been operating for more than 45 years without any significant deterioration in operating efficiency; therefore, this analysis of the remaining useful life of the equipment will be based on the anticipated useful life of the control device considered.

6.2.1. Clean Burn Technology

The useful life of a clean burn technology control system is conservatively estimated to be 20 years.

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[28] 40 CFR 51, Appendix Y, Section II.B.4.f

[29] U.S. EPA, "Air Pollution Control Cost Manual", available at: https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution#cost%20manual

7. SUMMARY & CONCLUSIONS

Based on a comprehensive review of the RBLC, available literature, and manufacturer's input of the available control technologies for the natural-gas fired turbines and 2SLB engines located at Kutz, Harvest has determined that $SoLoNO_X$ is the only technically feasible control option for the Solar turbine units. The cost of compliance to install the control on each of these units has been estimated based on manufacturer's input and EPA guidance. The estimated cost effectiveness and NO_X emission reduction for each turbine unit are summarized in Table 6.

Table 6. Summary of Cost Effectiveness and NO_X Reduction for Control of the Turbines at Kutz

Control Equipment	Unit	Emission Reduction (tpy)	Cost Effectiveness ($/ton)
Improved Combustion Technology ($SoLoNO_X$)	1	27.4	2,246
	2	25.5	2,412
	3	31.1	1,983
	4	3.4	23,111
	5	36.5	2,145
	6	41.0	1,910
	19	12.9	4,779
	20	30.1	2,043

It is projected that the useful life of these units will be 20 years, based on the life expectancy of the $SoLoNO_X$ control. Harvest estimates that an achievable compliance timeline to implement this control is 2-3 years.

Harvest has further determined that Clean Burn Technology is the only technically feasible control option for the 2SLB engines located at Kutz. The cost of compliance to install this control on each of these units has been estimated by Harvest. The estimated cost effectiveness and NO_X emission reduction for each engine unit are summarized in Table 7.

Table 7. Summary of Cost Effectiveness and NO_X Reduction for Control of the Engines at Kutz

Control Equipment	Unit	Emission Reduction (tpy)	Cost Effectiveness ($/ton)
Clean Burn Technology	16	121.1	1,021
	17	71.7	1,725
	18	70.0	1,767

It is projected that the useful life of these units will be 20 years, based on the life expectancy of the CBT control. The only anticipated energy and non-air impact of the CBT control will be an increase in CO emissions. Harvest estimates that 2-3 years would be an achievable compliance timeline to implement this control technology.

At this time, Harvest would like to reiterate their concerns regarding the limited manufacturer support available for these engines. It would be necessary to employ a third-party control vendor with significantly less unit-specific experience and familiarity to install this control. Harvest is concerned that the addition of this control equipment will be operationally detrimental due to this third-party involvement.

Furthermore, Harvest would like to advise the NMED of their judgement that the Kutz facility's potential contribution to regional haze at the Mesa Verde National Park Class I area is such that it does not justify their facility being selected for this assessment. There are hundreds of sources, both major and minor, located closer to the Class I area whose contribution has not been considered. Harvest would argue that only assessing high emitting sources at a limited number of facilities will not effectively address the visibility impairment problem, as required by the State under the RHR.

8. SUPPORTING DOCUMENTATION

Appendix A – RBLC Tables
Appendix B – Cost Analysis Calculations

APPENDIX A - RBLC TABLES

RBLC Analysis for Natural Gas Fired Turbines – NO_X Control

	Control Technology	Good Combustion Technique	Improved Combustion Technology (Low-NO_X Combustors, Ultra-Low NO_X Combustors and other improved combustion technology)[a]	Water/Steam Injection[b]	Selective Catalytic Reduction (SCR)[c]
IDENTIFY AIR POLLUTION CONTROL TECHNOLOGIES	Control Technology Description	NO_x emissions are caused by oxidation of nitrogen gas in the combustion air during fuel combustion. Primary combustion occurs at lower temperatures under oxygen-deficient conditions. By following EPA's "Good Combustion Practices" guidance document, good combustion practices can be maintained by training maintenance personnel on equipment maintenance, routinely scheduling inspections, conducting overhauls as appropriate for equipment involved, and using pipeline quality natural gas. By maintaining good combustion practices the unit will operate as intended with the optimal NO_x emissions.	Low-NO_x burners employ multi-staged combustion to inhibit the formation of NO_X. Primary combustion occurs at lower temperatures under oxygen-deficient conditions; secondary combustion occurs in the presence of excess air. This category includes Improved Combustion Technology Lean Head End Liners for the GE turbines assessed here.	Injected water/steam acts as a heat sink, lowering combustion zone peak temperatures, resulting in a decrease in thermal NO_X.	A nitrogen-based reagent (e.g., ammonia, urea) is injected into the exhaust stream downstream of the combustion unit. The reagent reacts selectively with NO_X to produce molecular N_2 and water in a reactor vessel containing a metallic or ceramic catalyst.
	Other Considerations	N/A	N/A	Results in a small efficiency penalty but an increase in power output. May increase CO and VOC emissions. Not available in certain models.	Typically, a small amount of ammonia is not consumed in the reactions and is emitted in the exhaust stream. These ammonia emissions are referred to as "ammonia slip." Unreacted reagent may form ammonium sulfates which may plug or corrode downstream equipment. Particulate-laden streams may blind the catalyst and may necessitate the application of a soot blower.
	RBLC Database Information	Included in RBLC for control of NO_X emissions from combustion turbines.	Included in RBLC for the control of NO_X emissions from combustion turbines.	Not included in RBLC for the control of NO_X emissions from combustion turbines; identified as a control option based on AP-42 Section 3.1.	Included in RBLC for the control of NO_X emissions from combustion turbines.
ELIMINATE TECHNICALLY INFEASIBLE OPTIONS	Feasibility Discussion	Technically feasible.	Technically infeasible. This option is not available for the turbine model.	Technically infeasible. This option is not available for the turbine model.	Technically feasible.
RANK REMAINING CONTROL TECHNOLOGIES	Overall Control Efficiency	Base Case			63%

a. California EPA, Air Resources Board, "Section 311 - Non-Selective Catalytic Reduction and Other NO_X Controls," http://www.arb.ca.gov/cap/manuals/cntrldev/sncr_etc/311nscr.htm

b. U.S. EPA, AP-42 Section 3.1, "Stationary Gas Turbines"

c. U.S. EPA, Office of Air Quality Planning and Standards, "Air Pollution Control Technology Fact Sheet (Selective Catalytic Reduction (SCR))," EPA-452/F-03-032.

Turbine RBLC Results
Completed RBLC Search on 9/19/2019 for a ten year period of 1/1/2019 to 09/19/201

RBLCID	FACILITY NAME	EPA REGION	PERMIT NUM	PROCESS NAME	PROCCESS TYPE	PRIMARY FUEL	THROUGHPUT	THROUGHPUT UNIT	PROCESS NOTES	POLLUTANT	CONTROL METHOD CODE	CONTROL METHOD DESCRIPTION	STANDARAD EMISSION LIMIT	STANDARD EMISSION LIMIT UNIT	STANDARD LIMIT AVERAGE TIME CONDITION	COST EFFECTIVENESS	INCREMENTAL COST EFFECTIVENESS	Cost Verified	DOLLAR YEAR USED IN COST ESTIMATES
AK-0083	KENAI NITROGEN OPERATIONS	10	AQ0083CPT06	Five (5) Natural Gas Fired Combustion Turbines	16.11	Natural Gas	37.6	MMBTU/H	Five (5) Natural Gas-Fired Solar Combustion Turbines rated at 37.6 MMBtu/hr each. Installed in 1976.	Nitrogen Oxides (NOx)	A	Selective Catalytic Reduction	0			0	0	N	
CA-1215	QUALCOMM INC.	9	2012--APP-002100	Cogeneration gas turbine	16.11	natural gas	4.37	MW	Manufacturer: Solar Turbines- Model: Mercury 50-6400R	Nitrogen Oxides (NOx)	A	SoLoNOx burner (Ultra lean Premix)	0			0	0	N	
LA-0331	CALCASIEU PASS LNG PROJECT	6	PDS-LA-805	Aeroderivative Simple Cycle Combustion Turbine	16.11	Natural Gas	263	MM BTU/h		Nitrogen Oxides (NOx)	B	Selective Catalytic Reduction (SCR), exclusive combustion of fuel gas, and good combustion practices.	0			0	0	N	
MI-0410	THETFORD GENERATING STATION	5	191-12	FG-PEAKERS: 2 natural gas fired simple cycle combustion turbines	16.11	natural gas	171	MMBTU/H	Two natural gas fired simple cycle combustion turbines each with an electrical generator (nominal 13MW each; 171 MMBtu/hr heat input rating each). Each turbine is limited to 343 MMscf of natural gas per 12-month rolling time period as determined at the end of each calendar month. Both turbines combined are limited to 5.15 MMscf of natural gas each calendar day.	Nitrogen Oxides (NOx)	P	Dry low-NOx combustors	0			0	0	N	
MI-0420	DTE GAS COMPANY--MILFORD COMPRESSOR STATION	5	185-15	FG-TURBINES	16.11	Natural gas	10504	HP	Five (5) simple cycle natural gas-fired combustion turbines (CTs) to drive compressors that will be used to transport natural gas through pipelines. The turbines are identified as EUTURBINE1, EUTURBINE2, EUTURBINE3, EUTURBINE4, and EUTURBINE5 within the flexible group FGTURBINES. There shall be no more than a combined total of 5 events (startup or shutdown) per clock hour. The total number of startup events for all units combined shall not exceed 500 events per 12-month rolling time period. The total number of shutdown events for all units combined shall not exceed 500 events per 12-month rolling time period. The maximum nominal rating of each turbine shall not exceed 10,504 HP (ISO).	Nitrogen Oxides (NOx)	A	Dry ultra-low NOx burners	0			0	0	N	
MI-0426	DTE GAS COMPANY - MILFORD COMPRESSOR STATION	5	185-15A	FGTURNBINES (5 Simple Cycle CTs: EUTURBINE1, EUTURBINE2, EUTURBINE3, EUTURBINE4, EUTURBINE5)	16.11	Natural gas	10504	HP	Five simple cycle natural gas-fired combustion turbines (CTs) to drive compressors that will be used to transport natural gas through pipelines (EUTURBINE1, EUTURBINE2, EUTURBINE3, EUTURBINE4, EUTURBINE5 in FGTURBINES). There shall be no more than a combined total of 5 events (startup or shutdown) per clock hour. The total number of startup events for all units combined shall not exceed 500 events per 12-month rolling time period. The total number of shutdown events for all units combined shall not exceed 500 events per 12-month rolling time period. The maximum nominal rating of each turbine shall not exceed 10,504 HP (ISO).	Nitrogen Oxides (NOx)	A	Dry ultra-low NOx burners.	0			0	0	N	
NV-0050	MGM MIRAGE	9	825	TURBINE GENERATORS - UNITS CC007 AND CC008 AT CITY CENTER	16.11	NATURAL GAS	4.6	MMBTU/H	THE TWO UNITS ARE IDENTICAL SOLAR MERCURY COMBUSTION GAS TURBINES FOR ELECTRIC POWER GENERATION. EACH UNIT IS RATED AT 4.6 MMBTU/HR, AND IS ALLOWED TO OPERATE 24 HOURS/DAY AND 8,760 HOURS/YEAR.	Nitrogen Oxides (NOx)	P	LEAN PRE-MIX TECHNOLOGY AND LIMITING THE FUEL TO NATURAL GAS ONLY	0.178	LB/MMBTU		0	0	N	
OK-0148	BUFFALO CREEK PROCESSING PLANT	6	2012-1026-C PSD	Small Combustion Turbines (<25MW)	16.11	Natural Gas	10179	Horsepower	Solar Taurus 70-10802S times 2.	Nitrogen Oxides (NOx)	P	Dry-Low NOx Combustion	0			0	0	N	
OK-0153	ROSE VALLEY PLANT	6	2012-1393-C PSD	TURBINES 9,443-HP SIEMENS SGT-200-2S	16.11	NATURAL GAS	9443	HP	THERE ARE TO BE LIKE-KIND TURBINES.	Nitrogen Oxides (NOx)	P	DRY LOW-NOx COMBUSTION.	0			0	0	N	
*PA-0314	BEECH HOLLOW	3	63-00922D	COMBUSTION TURBINE without DUCT BURNERS UNIT	16.11	Natural Gas	2433	MMBtu/hr	CEMS for NOx, CO	Nitrogen Oxides (NOx)	A	SCR	0			0	0	N	
TX-0642	SINTON COMPRESSOR STATION	6	PSDTX1304	Compression Turbine	16.11	natural gas	20000	hp	Two (2) 20,000 horsepower Solar Titan 130S turbines in natural gas pipeline compression service	Nitrogen Oxides (NOx)	P	Solar's SoLoNOx dry emission control technology	0			0	0	N	
TX-0685	GUADALUPE GENERATING STATION	6	106011 PSDTX1310	(2) simple cycle turbines	16.11	natural gas	190	MW	Four models are approved: GE7FA.03, GE7FA.04, GE7FA.05, or Siemens SW 5000F5. 383 MW to 454 MW total plant capacity.	Nitrogen Oxides (NOx)	B	DLN burners, limited operation	0			0	0	N	
*WI-0283	AFE, INC. â€"LCM PLANT	5	17-JJW-207	P90 â€" Natural Gas-Fired Emergency Generator	16.11	Natural Gas	9.51	mmBTU/hr	750 kW or 1,114 brake horsepower	Nitrogen Oxides (NOx)	P	Good Combustion Practices and the Use of Turbocharger and Aftercooler	0			0	0	N	
WY-0067	ECHO SPRINGS GAS PLANT	8	MD-7837	TURBINES S35-S36	16.11	NATURAL GAS	12555	HP	TWO (2) 12,555 HP SOLAR MARS 100-15000S TURBINES	Nitrogen Oxides (NOx)	N	SOLONOX	0			0	0	N	
WY-0067	ECHO SPRINGS GAS PLANT	8	MD-7837	TURBINE S34	16.11	NATURAL GAS	3856	HP	SOLAR CENTAUR 40-T4700S	Nitrogen Oxides (NOx)	N	SOLONOX	0			0	0	N	

RBLC Analysis for Natural Gas-Fired Lean-Burn RICE – NO_X Control

	Control Technology	Good Combustion Practices and Fuel Selection	Clean Burn Technology [a]	Selective Catalytic Reduction (SCR) [b,c]	Non-Selective Catalytic Reduction (NSCR) [c]
IDENTIFY AIR POLLUTION CONTROL TECHNOLOGIES	Control Technology Description	NO_x emissions are caused by oxidation of nitrogen gas in the combustion air during fuel combustion. This occurs due to high combustion temperatures and insufficiently mixed air and fuel in the cylinder where pockets of excess oxygen occur. By following EPA's "Good Combustion Practices" guidance document, good combustion practices can be maintained by training maintenance personnel on equipment maintenance, routinely scheduling inspections, conducting overhauls as appropriate for equipment involved, and using pipeline quality natural gas. By maintaining good combustion practices the unit will operate as intended with the optimal NO_x emissions.	Natural gas fueled engines that operate with a fuel-lean air/fuel ratio are capable of low NO_X emissions.	A nitrogen-based reagent (e.g., ammonia, urea) is injected into the exhaust stream downstream of the combustion unit. The reagent reacts selectively with NO_x to produce molecular N_2 and water in a reactor vessel containing a metallic or ceramic catalyst.	This technique uses residual hydrocarbons and CO in rich-burn engine exhaust as a reducing agent for NO_x. In an NSCR, hydrocarbons and CO are oxidized by O_2 and NO_x. The excess hydrocarbons, CO, and NO_x pass over a catalyst (usually a noble metal such as platinum, rhodium, or palladium) that oxidizes the excess hydrocarbons and CO to H_2O and CO_2, while reducing NO_x to N_2.[b]
	Other Considerations	N/A	N/A	Typically, a small amount of ammonia is not consumed in the reactions and is emitted in the exhaust stream. These ammonia emissions are referred to as "ammonia slip." Unreacted reagent may form ammonium sulfates which may plug or corrode downstream equipment. Particulate-laden streams may blind the catalyst and may necessitate the application of a soot blower.	N/A
ELIMINATE TECHNICALLY INFEASIBLE OPTIONS	RBLC Database Information	Included in RBLC for the control of NO_x emissions from large natural gas-fired lean-burn stationary internal combustion engines.	Included in RBLC for the control of NO_x emissions from large natural gas-fired lean-burn stationary internal combustion engines.	Not included in RBLC for the control of NO_x emissions from large natural gas-fired lean-burn stationary internal combustion engines.	Not included in RBLC for the control of NO_X emissions from large natural gas-fired lean-burn stationary internal combustion engines.
	Feasibility Discussion	Technically feasible.	Technically feasible.	Technically infeasible. Site and unit-specific complications exclude SCR as a control option for the 2SLB engines at this facility.	Technically infeasible. The NSCR technique is limited to engines with normal exhaust oxygen levels of 4 percent or less. This includes 4-stroke rich-burn naturally aspirated engines and some 4-stroke rich-burn turbocharged engines. Lean-burn engines could not be retrofitted with NSCR control because of the reduced exhaust temperatures.
RANK REMAINING CONTROL TECHNOLOGIES	Overall Control Efficiency	Base Case	80 - 93%		

a. U.S. EPA, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document – NOX Emissions from Stationary Reciprocating Internal Combustion Engines", EPA-453/R-93-032, Section 5.2.5.4, July 1993

b. U.S. EPA, Office of Air Quality Planning and Standards, "Air Pollution Control Technology Fact Sheet (Selective Catalytic Reduction (SCR))," EPA-452/F-03-032.

c. U.S. EPA, AP-42, Section 3.2, "Natural Gas-Fired Reciprocating Engines"

Engine RBLC Results
Completed RBLC Search on 9/19/2019 for a ten year period of 1/1/2019 to 09/19/2019

RBLCID	FACILITY NAME	EPA REGION	PERMIT NUM	PROCESS NAME	PROCCESS TYPE	PRIMARY FUEL	THROUGHPUT	THROUGHPUT UNIT	PROCESS NOTES	POLLUTANT	CONTROL METHOD CODE	CONTROL METHOD DESCRIPTION	STANDARAD EMISSION LIMIT	STANDARD EMISSION LIMIT UNIT	STANDARD LIMIT AVERAGE TIME CONDITION	COST EFFECTIVENESS	INCREMENTAL COST EFFECTIVENESS	Cost Verified	DOLLAR YEAR USED IN COST ESTIMATES
CA-1192	AVENAL ENERGY PROJECT	9	SJ 08-01	EMERGENCY IC ENGINE	17.13	NATURAL GAS	550	KW	UNIT IS 860 HP	Nitrogen Oxides (NOx)	A	SCR, OPERATIONAL LIMIT OF 50 HRS/YR	0			0	0	N	
CA-1222	KYOCERA AMERICA INC.	9	2011-APP-001634	ICE: Spark Igition	17.13	natural gas	2889	bhp	anther one is 2328 bhp	Nitrogen Oxides (NOx)	A	SCR with process control NOx monitor	0			0	0	N	
CA-1240	GOLD COAST PACKING	9	14646	Internal Combustion Engine	17.13	Natural gas	881	bhp		Nitrogen Oxides (NOx)	A	SCR catalyst-Urea injection	0			0	0	N	
*FL-0368	NUCOR STEEL FLORIDA FACILITY	4	1050472-001-AC	Emergency Engines	17.13	Natural gas	0		Two 2,000-kW Emergency Natural Gas-Fired Generators & One Emergency Natural Gas-Fired 500 HP Fire Pump	Nitrogen Oxides (NOx)	P	Good combustion practices	0			0	0	N	
IN-0167	MAGNETATION LLC	5	181-32081-00054	EMERGENCY GENERATOR	17.13	NATURAL GAS	620	HP	EMERGENCY NATURAL GAS GENERATOR, IDENTIFIED AS EU017, EXHAUSTS TO STACK SV016.	Nitrogen Oxides (NOx)	P	USE OF NATURAL GAS AND GOOD COMBUSTION PRACTICES	0			0	0	N	
*KS-0030	MID-KANSAS ELECTRIC COMPANY, LLC - RUBART STATION	7	C-13309	Spark ignition RICE emergency AC generators	17.13	Natural gas	450	kW	Two (2) spark ignition emergency AC generators, each rated at 450 kW (approximately 604 BHP), which shall burn only natural gas for fuel for the purpose of providing emergency power.	Nitrogen Oxides (NOx)	N		0			0	0	N	
*KS-0030	STATION	7	C-13309	(EGUs)	17.13	Natural Gas	10	MW	G20CM34), used to generate electricity. The generating capacity of	Nitrogen Oxides (NOx)	N		0			0	0	N	
KS-0035	LACEY RANDALL GENERATION FACILITY, LLC	7	C-10593	spark ignition four stroke lean burn reciprocating internal combustion engine (RICE) electric generating units (EGUs)	17.13	Natural gas	12526	BHP	Ten new spark ignition RICE EGUs (Wartsila model 20V34SG), used to generate electricity. The generating capacity of each EGU will be 9.34 megawatts (approximately 12,526 BHP). Each EGU shall be equipped with a selective catalytic reduction (SCR) system and an oxidation catalyst, and shall burn only pipeline quality natural gas for fuel.	Nitrogen Oxides (NOx)	A	Selective Catalytic Reduction (SCR) system and oxidation catalyst	0			0	0	N	
LA-0257	SABINE PASS LNG TERMINAL	6	PSD-LA-703(M3)	Generator Engines (2)	17.13	Natural Gas	2012	hp		Nitrogen Oxides (NOx)	P	Comply with 40 CFR 60 Subpart JJJJ	2	GRAM/B-HP-H		0	0	N	
LA-0287	ALEXANDRIA COMPRESSOR STATION	6	PSD-LA-787	Emergency Generator Reciprocating Engine (G30, EQT 15)	17.13	Natural Gas	1175	HP	Non-emergency operation limited to 100 hours per year. Engine is subject to NSPS Subpart JJJJ.	Nitrogen Oxides (NOx)	P	Good combustion practices; use of natural gas as fuel; limit non-emergency use to <= 100 hours per year; adherence to the permittee's operating and maintenance practices	2	G/BHP-HR		0	0	N	
LA-0292	HOLBROOK COMPRESSOR STATION	6	PSD-LA-769(M-1)	Waukesha 16V-275GL Compressor Engines Nos. 1-12	17.13	Natural Gas	5000	HP		Nitrogen Oxides (NOx)	P	Lean-burn combustion, use of natural gas as fuel, good equipment design, and proper combustion techniques	0.45	G/BHP-HR		0	0	N	
MI-0393	RAY COMPRESSOR STATION	5	206-09	Five spark ignition internal combustion engines	17.13	natural gas	32	MMBTU/H	Five (5) natural gas fired spark ignition ICEs, Caterpillar G3616, 4735 hp lean burn engines with 2 way oxidation catalysts.	Nitrogen Oxides (NOx)	N	low emission design and good combustion practices	0			0	0	N	
MI-0393	RAY COMPRESSOR STATION	5	206-09	Emergency generator	17.13	natural gas	500	H/YR	This is an emergency generator which is limited to 500 hours per year of operation.	Nitrogen Oxides (NOx)	N		0			0	0	N	
MI-0401	MIDLAND POWER STATION	5	24-11B	Emergency generator	17.13	Natural gas	1200	kW output	This is a 1200kW (output) natural gas fired emergency generator. The engine was manufactured after 2009	Nitrogen Oxides (NOx)	N		0			0	0	N	
MI-0412	HOLLAND BOARD OF PUBLIC WORKS - EAST 5TH STREET	5	107-13	Emergency Engine--natural gas (EUNGENGINE)	17.13	natural gas	1000	kW	A 1,000 kilowatts (kW) natural gas-fueled emergency engine manufactured in 2013. The engine is used to charge the batteries in the uninterruptible power supply (UPS) battery system (EUNGENGINE). Restricted to 500 hours/year on a 12-month rolling time period basis.	Nitrogen Oxides (NOx)	P	Good combustion practices	0			0	0	N	
MI-0420	DTE GAS COMPANY--MILFORD COMPRESSOR STATION	5	185-15	EUN_EM_GEN	17.13	Natural gas	225	H/YR	A 1,506 kilowatts (kW) natural gas fueled emergency engine manufactured in 2011 or later. The engine is used to provide electrical power to the station and support equipment in the event power from the public utility grid system is lost (EUN_EM_GEN). Restricted to 225 hours/year on a 12-month rolling time period basis.	Nitrogen Oxides (NOx)	B	Low NOx design (turbo charger and after cooler) and good combustion practices.	0			0	0	N	
MI-0424	HOLLAND BOARD OF PUBLIC WORKS - EAST 5TH STREET	5	107-13C	EUNGENGINE (Emergency engine--natural gas)	17.13	Natural gas	500	H/YR	A 1,462 HP natural gas-fueled emergency engine manufactured in 2016 serving a 1,040 kW generator. The engine is used to charge the batteries in the uninterruptible power supply (UPS) battery system (EUNGENGINE). Restricted to 144 hours/year on a 12-month rolling time period basis.	Nitrogen Oxides (NOx)	P	Good combustion practices.	0			0	0	N	
MI-0426	DTE GAS COMPANY - MILFORD COMPRESSOR STATION	5	185-15A	EUN_EM_GEN (Natural gas emergency engine).	17.13	Natural gas	205	H/YR	A nominally rated 1,300 electrical kilowatts (ekW) output emergency genset containing a 1,818 HP natural gas fueled engine manufactured in 2011 or later. The engine is used to provide electrical power to the station and support equipment in the event power from the public utility grid system is lost (EUN_EM_GEN). Restricted to 205 hours/year on a 12-month rolling time period basis.	Nitrogen Oxides (NOx)	B	Low NOx design (turbo charger and after cooler) and good combustion practices.	0			0	0	N	
OK-0148	BUFFALO CREEK PROCESSING PLANT	6	2012-1026-C PSD	Large Internal Combustion Engines (>500 hp)	17.13	Natural Gas	1775	Horsepower	Caterpillar G3606LE 4SLB times 6.	Nitrogen Oxides (NOx)	P	Ultra Lean Burn	0			0	0	N	
OK-0148	BUFFALO CREEK PROCESSING PLANT	6	2012-1026-C PSD	Large Internal Combustion Engines (>500 hp)	17.13	Natural Gas	2370	Horsepower	Caterpillar G3608LE 4SLB times 4.	Nitrogen Oxides (NOx)	P	Ultra Lean Burn	0			0	0	N	
OK-0153	ROSE VALLEY PLANT	6	2012-1393-C PSD	COMPRESSOR ENGINE 1,775-HP CAT G3606LE	17.13	NATURAL GAS	1775	HP	THERE ARE TO BE TEN (10) LIKE-KIND ENGINES.	Nitrogen Oxides (NOx)	N		0			0	0	N	
OK-0153	ROSE VALLEY PLANT	6	2012-1393-C PSD	EMERGENCY GENERATORS 2,889-HP CAT G3520C IM	17.13	NATURAL GAS	2889	HP	THERE ARE TO BE TWO (2) ENGINES, EACH EQUIPPED W/AN OXIDATION CATALYST. THESE WILL BE LIMITED USE (< 750 HOURS PER YEAR).	Nitrogen Oxides (NOx)	P	LEAN-BURN COMBUSTION.	0			0	0	N	
PA-0287	WELLING COMPRESSOR STATION	3	63-00958	CATERPILLAR G3516B COMPRESSOR ENGINES (2)	17.13	Natural Gas	0			Nitrogen Oxides (NOx)	N		6.66	T/YR	EACH ENGINE	0	0	N	
PA-0287	WELLING COMPRESSOR STATION	3	63-00958	WAUKESHA P9390GSI COMPRESSOR ENGINES (4) (1980 BHP)	17.13	Natural Gas	0			Nitrogen Oxides (NOx)	A	3-way catalyst, Johnson Matthey	3.82	T/YR	EACH ENGINE	0	0	N	
PA-0297	KELLY IMG ENERGY LLC/KELLY IMG PLT	3	16-161A	3.11 MW GENERATORS (WAUKESHA) #1 and #2	17.13	Natural Gas	0			Nitrogen Oxides (NOx)	N		0			0	0	N	
PA-0301	CARPENTER COMPRESSOR STATION	3	GP5-63-00987	Three Four Stroke Lean Burn Engine - Caterpillar G3608 TA, 2370 BHP	17.13	Natural Gas	0		Controlled by oxidation Catalyst, regulated by automatic air/fuel ratio controllers.	Nitrogen Oxides (NOx)	N		0			0	0	N	
PA-0301	CARPENTER COMPRESSOR STATION	3	GP5-63-00987	One four stroke lean burn engine, Caterpillar Model G3612 TA, 3550 bhp	17.13	Natural Gas	0		Controlled by Oxidation catalyst, regulated by an integrated automatic air/fuel ration controller.	Nitrogen Oxides (NOx)	N		0			0	0	N	
PA-0302	CLERMONT COMPRESSOR STATION	3	GP5-24-180A	Spark Ignited 4 stroke Rich Burn Engine (7 units)	17.13	Natural Gas	0		Spark Ignited 4 stroke Rich Burn Engine (7 units)	Nitrogen Oxides (NOx)	A	NSCR	0			0	0	N	
TX-0642	SINTON COMPRESSOR STATION	6	PSDTX1304	Emergency Engine	17.13	natural gas	1328	hp	1328 horsepower standby generator operating no more than 100 hours per year	Nitrogen Oxides (NOx)	N		0			0	0	N	
TX-0680	SONORA GAS PLANT	6	106139 PSDTX1316	Refrigeration compressor engine	17.13	natural gas	1183	hp	(4) Caterpillar 3516 ultra-lean burn compressor engines at 1,183 hp each	Nitrogen Oxides (NOx)	P	ultra-lean burn technology	0			0	0	N	
TX-0680	SONORA GAS PLANT	6	106139 PSDTX1316	Recompression compressor engine	17.13	natural gas	1380	hp	(8) ultra-lean burn Caterpillar 3516 engines at 1,380 hp each	Nitrogen Oxides (NOx)	P	ultra-lean burn technology	0			0	0	N	
TX-0692	RED GATE POWER PLANT	6	106544 PSDTX1322	(12) reciprocating internal combustion engines	17.13	natural gas	18	MW	12 â€“ 18 MW Wartsila 18V50SG natural gas-fired engines, each with an associated electric generator	Nitrogen Oxides (NOx)	A	Selective Catalytic Reduction (SCR)	0			0	0	N	
TX-0755	RAMSEY GAS PLANT	6	117323 AND PSDTX1392,O-3546	Internal Combustion Compressor Engines	17.13	Residue gas equivalent to natural gas	206149	MMBtu/yr	Each cryogenic plant at the Ramsey Gas Plant will have 5 natural gas-fired compressor engines. The residue gas from each plant will be compressed by five compressors.	Nitrogen Oxides (NOx)	P	Ultra Lean-burn engines firing natural gas	0			0	0	N	
WY-0066	MEDICINE BOW IGL PLANT	8	CT-5873	BLACK START GENERATOR 1	17.13	NATURAL GAS	2889	HP	250 HOURS OF OPERATION	Nitrogen Oxides (NOx)	N	LIMITED OPERATING HOURS (250 HR/YR)	0.8	T/YR	ANNUAL	0	0	N	
WY-0066	MEDICINE BOW IGL PLANT	8	CT-5873	BLACK START GENERATOR 2	17.13	NATURAL GAS	2889	HP	LIMITED OPERATING HOURS (250 HR/YR)	Nitrogen Oxides (NOx)	N	LIMITED OPERATING HOURS (250 HR/YR)	0.8	T/YR	ANNUAL	0	0	N	
WY-0066	MEDICINE BOW IGL PLANT	8	CT-5873	BLACK START GENERATOR 3	17.13	NATURAL GAS	2889	HP	LIMITED OPERATING HOURS (250 HR/YR)	Nitrogen Oxides (NOx)	N	LIMITED OPERATING HOURS (250 HR/YR)	0.8	T/YR	ANNUAL	0	0	N	

APPENDIX B – COST ANALYSIS CALCULATIONS

Turbine Cost Analysis Interest Rate: 5.50%
All Units Period (yrs): 20

Control Equipment	Unit	Capital Cost	Total Annual Cost*	Emission Reduction	Cost Effectiveness
		($)	($)	(tpy)	($/ton)
Improved Combustion Technology (SoLoNO$_X$)	1	467,300	61,603	27.4	2,246
	2	467,300	61,603	25.5	2,412
	3	467,300	61,603	31.1	1,983
	4	667,300	78,339	3.4	23,111
	5	667,300	78,339	36.5	2,145
	6	667,300	78,339	41.0	1,910
	19	467,300	61,603	12.9	4,779
	20	467,300	61,603	30.1	2,043

* Total Annual Cost includes the annualized capital cost as well as the direct and indirect annual operating costs.

Control Equipment	Unit	Capital Cost	Total Annual Cost*	Emission Reduction	Cost Effectiveness
		($)	($)	(tpy)	($/ton)
Clean Burn Technology	16	1,000,000	123,679	121.1	1,021
	17	1,000,000	123,679	71.7	1,725
	18	1,000,000	123,679	70.0	1,767

* Total Annual Cost includes the annualized capital cost as well as the direct and indirect annual operating costs.

Solar Centaur 40	Interest Rate:	5.50%	
Unit 1	Period (yrs):	20	<-- EPA Cost Control Manual
	Model:	T4002	

Base (67.61 ppm)				
NO_X ppm:		67.61	ppm	<-- Converted from 2016 EI calculations and data
NO_X tpy:		43.52	tpy	<-- From 2016 EI calculations
SoLoNO$_X$ (25 ppm)				
NO_X guarantee:		25	ppm	<-- from Solar
NO_X tpy:		16.09	tpy	
Total Cap Investment	$	467,300		<-- from Solar
Annualized TCI:	$	39,103		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	22,500		<-- from Solar
Total Annual Costs:	$	61,603		
Emissions Reduction:		27.43	tpy	
Cost Effectiveness:	**$**	**2,245.81**	**$/ton**	

Solar Centaur 40	Interest Rate:	5.50%	
Unit 2	Period (yrs):	20	<-- EPA Cost Control Manual
	Model:	T4002	

Base (67.61 ppm)				
NO_X ppm:		67.61	ppm	<-- Converted from 2016 EI calculations and data
NO_X tpy:		40.52	tpy	<-- From 2016 EI calculations

SoLoNO$_X$ (25 ppm)				
NO_X guarantee:		25	ppm	<-- from Solar
NO_X tpy:		14.98	tpy	
Total Cap Investment	$	467,300		<-- from Solar
Annualized TCI:	$	39,103		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	22,500		<-- from Solar
Total Annual Costs:	$	61,603		
Emissions Reduction:		25.54	tpy	
Cost Effectiveness:	**$**	**2,412.48**	**$/ton**	

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Kutz Canyon Processing Plant

Solar Centaur 40
Unit 3

Interest Rate: 5.50%
Period (yrs): 20 <-- EPA Cost Control Manual
Model: T4002

Base (67.61 ppm)				
NO_X ppm:		67.61	ppm	<-- Converted from 2016 EI calculations and data
NO_X tpy:		49.29	tpy	<-- From 2016 EI calculations

SoLoNO$_X$ (25 ppm)				
NO_X guarantee:		25	ppm	<-- from Solar
NO_X tpy:		18.23	tpy	
Total Cap Investment	$	467,300		<-- from Solar
Annualized TCI:	$	39,103		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	22,500		<-- from Solar
Total Annual Costs:	$	61,603		
Emissions Reduction:		31.06	tpy	
Cost Effectiveness:	**$**	**1,983.09**	**$/ton**	

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Solar Centaur 40	Interest Rate:	5.50%	
Unit 4	Period (yrs):	20	<-- EPA Cost Control Manual
	Model:	T4002	

Base (67.61 ppm)				
NO_X ppm:		67.61	ppm	<-- Converted from 2016 EI calculations and data
NO_X tpy:		5.38	tpy	<-- From 2016 EI calculations

SoLoNO$_X$ (25 ppm)				
NO_X guarantee:		25	ppm	<-- from Solar
NO_X tpy:		1.99	tpy	
Total Cap Investment	$	667,300		<-- from Solar
Annualized TCI:	$	55,839		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	22,500		<-- from Solar
Total Annual Costs:	$	78,339		
Emissions Reduction:		3.39	tpy	
Cost Effectiveness:	**$**	**23,110.79**	**$/ton**	

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Solar Centaur 40	Interest Rate:	5.50%	
Unit 5	Period (yrs):	20	<-- EPA Cost Control Manual
	Model:	T4002	

Base (67.61 ppm)				
NO_X ppm:		67.61	ppm	<-- Converted from 2016 EI calculations and data
NO_X tpy:		57.96	tpy	<-- From 2016 EI calculations
SoLoNO$_X$ (25 ppm)				
NO_X guarantee:		25	ppm	<-- from Solar
NO_X tpy:		21.43	tpy	
Total Cap Investment	$	667,300		<-- from Solar
Annualized TCI:	$	55,839		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	22,500		<-- from Solar
Total Annual Costs:	$	78,339		
Emissions Reduction:		36.53	tpy	
Cost Effectiveness:	**$**	**2,144.52**	**$/ton**	

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Kutz Canyon Processing Plant

Solar Centaur 40	Interest Rate:		5.50%	
Unit 6	Period (yrs):		20	<-- EPA Cost Control Manual
	Model:	T4002		

Base (67.61 ppm)				
NO_X ppm:		67.61	ppm	<-- Converted from 2016 EI calculations and data
NO_X tpy:		65.08	tpy	<-- From 2016 EI calculations

SoLoNO$_X$ (25 ppm)				
NO_X guarantee:		25	ppm	<-- from Solar
NO_X tpy:		24.06	tpy	
Total Cap Investment	$	667,300		<-- from Solar
Annualized TCI:	$	55,839		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	22,500		<-- from Solar
Total Annual Costs:	$	78,339		
Emissions Reduction:		41.01	tpy	
Cost Effectiveness:	**$**	**1,910.07**	**$/ton**	

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Kutz Canyon Processing Plant

Solar Centaur 40	Interest Rate:		5.50%	
Unit 19	Period (yrs):		20	<-- EPA Cost Control Manual
	Model:	T4001		

Base (67.61 ppm)				
NO_X ppm:		67.61	ppm	<-- Converted from 2016 EI calculations and data
NO_X tpy:		20.45	tpy	<-- From 2016 EI calculations

SoLoNO$_X$ (25 ppm)				
NO_X guarantee:		25	ppm	<-- from Solar
NO_X tpy:		7.56	tpy	
Total Cap Investment	$	467,300		<-- from Solar
Annualized TCI:	$	39,103		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	22,500		<-- from Solar
Total Annual Costs:	$	61,603		
Emissions Reduction:		12.89	tpy	
Cost Effectiveness:	**$**	**4,779.25**	**$/ton**	

Solar Centaur 40	Interest Rate:	5.50%	
Unit 20	Period (yrs):	20	<-- EPA Cost Control Manual
	Model:	T4001	

Base (67.61 ppm)				
NO$_X$ ppm:		67.61	ppm	<-- Converted from 2016 EI calculations and data
NO$_X$ tpy:		47.83	tpy	<-- From 2016 EI calculations
SoLoNO$_X$ (25 ppm)				
NO$_X$ guarantee:		25	ppm	<-- from Solar
NO$_X$ tpy:		17.69	tpy	
Total Cap Investment	$	467,300		<-- from Solar
Annualized TCI:	$	39,103		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	22,500		<-- from Solar
Total Annual Costs:	$	61,603		
Emissions Reduction:		30.15	tpy	
Cost Effectiveness:	**$**	**2,043.49**	**$/ton**	

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Kutz Canyon Processing Plant

Clark HRA-8	Interest Rate:	5.50%	
Unit 16	Period (yrs):	20	<-- EPA Cost Control Manual
	Rating:	723	hp

Base

NO_X tpy:	151.37	tpy	<-- From 2016 EI calculations

Clean Burn (80% Reduction)[1]

NO_X tpy:		30.27	tpy	<-- Reduction based on NO_X Emission Controls Doc.[1]
Total Cap Investment	$	1,000,000		<-- Estimate from Harvest
Annualized TCI:	$	83,679		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	40,000		<-- Estimate from Harvest
Total Annual Costs:	$	123,679		
Emissions Reduction:		121.09	tpy	
Cost Effectiveness:	**$**	**1,021.35**	**$/ton**	

[1] From Assessment of Non-EGU NO_X Emission Controls, Cost of Controls, and Timeline for Compliance (Docket ID No. EPA-HQ-OAR-2015-0500) Section 5.3.

Harvest Four Corners, LLC
Kutz Canyon Processing Plant

Clark HRA-8	Interest Rate:	5.50%	
Unit 17	Period (yrs):	20	<-- EPA Cost Control Manual
	Rating:	723	hp

Base				
NO$_X$ tpy:		89.63	tpy	<-- From 2016 EI calculations
Clean Burn (80% Reduction)[1]				
NO$_X$ tpy:		17.93	tpy	<-- Reduction based on NO$_X$ Emission Controls Doc.[1]
Total Cap Investment	$	1,000,000		<-- Estimate from Harvest
Annualized TCI:	$	83,679		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	40,000		<-- Estimate from Harvest
Total Annual Costs:	$	123,679		
Emissions Reduction:		71.71	tpy	
Cost Effectiveness:	**$**	**1,724.79**	**$/ton**	

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[1] From Assessment of Non-EGU NO$_X$ Emission Controls, Cost of Controls, and Timeline for Compliance (Docket ID No. EPA-HQ-OAR-2015-0500) Section 5.3.

Harvest Four Corners, LLC
Kutz Canyon Processing Plant

Clark HRA-8	Interest Rate:	5.50%	
Unit 18	Period (yrs):	20	<-- EPA Cost Control Manual
	Rating:	723	hp

Base				
NO$_X$ tpy:		87.50	tpy	<-- From 2016 EI calculations

Clean Burn (80% Reduction)[1]				
NO$_X$ tpy:		17.50	tpy	<-- Reduction based on NO$_X$ Emission Controls Doc.[1]
Total Cap Investment	$	1,000,000		<-- Estimate from Harvest
Annualized TCI:	$	83,679		<-- Based on interest rate, year and TCI
Annual O&M Costs:	$	40,000		<-- Estimate from Harvest
Total Annual Costs:	$	123,679		
Emissions Reduction:		70.00	tpy	
Cost Effectiveness:	**$**	**1,766.84**	**$/ton**	

[1] From Assessment of Non-EGU NO$_X$ Emission Controls, Cost of Controls, and Timeline for Compliance (Docket ID No. EPA-HQ-OAR-2015-0500) Section 5.3.