A Nitrogen Oxide Limit of 2.5 ppm or Less Is the Best-In-Class Control Level for the Proposed Duke University 21.7 MW CHP Plant, Not 25 ppm as Proposed by Duke Energy

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Duke Energy proposed a 25 parts per million (ppm) nitrogen oxides (NO_x) limit in its October 17, 2016 Certificate for Public Convenience and Necessity (CPCN) application to the North Carolina Utilities Commission for a 21.7 MW gas turbine at the proposed combined heat and power (CHP) plant to be located at Duke University. A NO_x limit of 2.0 to 2.5 ppm using selective catalytic reduction (SCR) is the best-in-class control level for gas turbine CHP plants. Gas turbine CHP plants at Cornell University, Massachusetts Institute of Technology, and the University of California San Diego, for example, meet a NO_x limit of 2.5 ppm or less. Duke Energy will avoid approximately $2.4 million in capital cost by not adding catalytic emission controls to the proposed CHP plant at Duke University. However, air emissions from the proposed CHP plant will be at least ten times greater than emission levels achievable with best-in-class catalytic control systems. Existing Duke Energy natural gas-fired power plants in North Carolina, specifically the Buck and Dan River combined-cycle gas turbine power plants, are subject to a 2.5 ppm NO_x permit limit.

A. Applicable North Carolina Air Emission Limitations

The federal Clean Air Act establishes ambient air quality standards for six pollutants, known as criteria pollutants: nitrogen dioxide, sulfur dioxide, ozone [controlled by regulating two groups of ozone precursor compounds - nitrogen oxides (NO_x) and volatile organic compounds (VOC)], carbon monoxide, and lead. The federal criteria pollutant major source threshold for gas turbine power plants is 100 tons per year (tpy).[1] Major sources must apply best available control technology (BACT). BACT is a technology-forcing standard intended to result in the lowest cost-effective emission rate achievable.

The annual potential-to-emit of the Titan 250 gas turbine proposed by Duke Energy for use in the Duke University CHP plant, at a NO_x limit of 25 ppm, is 83.7 tpy of NO_x.[2] This is below the 100 tpy NO_x major source threshold and therefore BACT is not explicitly required for the Duke University CHP project. The federal New Source Performance Standard (NSPS) for gas turbines, NSPS Subpart KKKK, does apply to the project and imposes a NO_x limit of 25 ppm. As a result, the NO_x limit for the Duke University CHP gas turbine cannot be higher than 25 ppm, though Duke Energy could voluntarily agree to a lower NO_x limit.

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[1] EPA Memorandum - E. Lillis, Permits Programs Branch Chief, *Determining Prevention of Significant Deterioration (PSD) Applicability Thresholds for Gas Turbine Based Facilities*, February 2, 1993.
[2] Metropolitan Health Department (Nashville, TN), Tennessee Gas Pipeline Company, LLC Compressor Station 563, Permit Number: C-28XX, two Solar Titan 250-30000S gas turbines, September 11, 2015, p. 3.

For example, Duke Energy has already voluntarily proposed a NO_x limit on another industrial-scale gas turbine project in North Carolina that is stricter than the minimum requirement. Duke Energy owns 47 percent of the proposed Atlantic Coast Pipeline (ACP) project.[3] This pipeline will include three compressor stations, in West Virginia, Virginia, and North Carolina.[4] All eleven Solar Turbines, Inc. gas turbines used to power the compressors located at the three ACP compressor stations, including one Titan 130 gas turbine, will voluntarily utilize SCR as a "best in class" NO_x control technology.[5,6] The three Solar Turbines, Inc. gas turbines to be located at the North Carolina compressor station in Northampton County, a Taurus 70, a Centaur 50L, and a Centaur 40 turbine, will be substantially smaller than the Titan 250 turbine proposed for the Duke University CHP plant. Yet these gas turbines will utilize SCR for NO_x control.[7]

B. Gas Turbine CHP NO_x Limits at Comparable University CHP Plants

Many colleges and universities operate CHP plants. Some of these educational institutions utilize the same make of turbine, the Solar Turbines, Inc. Titan gas turbine proposed for the Duke University CHP plant. The turbine make and associated NO_x limit at selected universities with CHP plants are provided in Table 1. The control system employed to reduce CO and VOC emissions is also identified.

Table 1. Turbine make and NO_x limit at selected university CHP plants

University	Turbine make	NO_x control technology	NO_x limit (ppm at 15% O_2)	CO/VOC control technology	Startup year
UC San Diego[8]	Solar Titan 130 (2 turbines)	SCONO$_x$™	2.5	SCONO$_x$™	2001
Cornell[9]	Solar Titan 130 (2 turbines)	SCR	2.5	OxCat	2009
MIT[10] (proposed)	Solar Titan 250 (2 turbines)	SCR	2.0	OxCat	2019
Duke[11] (proposed)	Solar Titan 250 (1 turbine)	none	25	none	2019

SCONO$_x$™: proprietary catalytic reduction technology
SCR: selective catalytic reduction

[3] Richmond Times-Dispatch, *Dominion retains controlling share in pipeline company restructuring after Piedmont sale*, October 3, 2016.
[4] Atlantic Coast Pipeline, LLC, *Dominion Transmission, Inc. Supply Header Project, FERC Docket No. CP15-554-000, Resource Report 9 Air and Noise Quality*, September 2015, p. 9-15.
[5] Ibid, p. 9-24. See **Attachment A**.
[6] Ibid, p. 9-43.
[7] Ibid, p. 9-43.
[8] California Air Resources Board, *Report to the Legislature: Gas-Fired Power Plant NO_x Emission Controls and Related Environmental Impacts*, May 2004, p. 17.
[9] Combined Cycle Journal, *Transforming a Steam Plant into a Full Service Utility - Cornell Combined Heat and Power Plant*, 2nd quarter 2010, p. 1.
[10] MIT, *Single Environmental Impact Report – MIT Central Utilities Plant Second Century Project, EEA#15453*, May 13, 2016, p. 1-10.
[11] Duke Energy Carolinas, *Application of Duke Energy Carolinas, LLC for a Certificate or Public Convenience and Necessity to Construct 21 MW Combined Heat and Power Facility at Duke University in Durham County, North Carolina, Docket No. E-7, Sub 1122*, October 17, 2016, p. 3.

Numerous CHP plants at comparable universities to Duke University achieve NO_x emission rates that are one-tenth or less the NO_x emission rate proposed by Duke Energy for the Duke University CHP plant. Neither Duke Energy or Duke University are constrained by North Carolina air pollution control regulations from voluntarily accepting a NO_x permit limit of 2.5 ppm or less.

Duke Energy Carolinas already owns and operates two gas-turbine combined cycle power plants, the 668 MW Buck plant in Rowan County, NC, and the 651 MW Dan River plant in Rockingham, NC, that have NO_x limits of 2.5 ppm. Each of these power plants incorporates two gas turbines of approximately 170 MW each and a single steam turbine-generator.[12] Both of these power plants are classified as federal major NO_x sources, as uncontrolled NO_x emissions would exceed 100 tpy. In addition to using SCR for NO_x control, the Buck and Dan River combined cycle units are also equipped with OxCat for CO and VOC control.[13,14]

Modifications to major sources that increase NO_x emissions by 40 tpy or more are subject to BACT.[15] If Duke Energy were to collocate the proposed 21.7 MW CHP plant at its existing Buck or Dan River combined cycle plants, the CHP plant, with uncontrolled NO_x emissions of 83.7 tpy, would be subject to BACT as a modification to an existing major source and be required to meet the 2.5 ppm NO_x limit applicable at those power plants.

C. Cost of Best-in-Class Air Emission Controls for Duke University CHP Plant

In March 2015, the EPA published a cost estimate for SCR, OxCat, and continuous emission monitors for a 21.7 MW gas turbine in CHP service.[16] The turbine characteristics assumed by the EPA match the heat input and exhaust gas flowrate of the Titan 250.[17,18] The EPA relied on SCR vendor quotations in its March 2015 CHP

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[12] Duke Energy Carolinas, *Duke Energy Carolinas, LLC 2016 Integrated Resource Plan and 2016 REPS Compliance Plan, Docket No. E-100, Sub 147*, September 1, 2016, p. 82. Buck summer rating: combustion turbine 11 = 176.3 MW; combustion turbine 12 = 175.1 MW; steam turbine 10 = 316.8 MW. Dan River summer rating: combustion turbine 8 = 165 MW; combustion turbine 9 = 166 MW; steam turbine 7 = 320 MW.
[13] NCDEQ, Air Quality Permit No. 03455T31, Facility ID: 7900015, Duke Energy Carolinas LLC - Dan River Combined Cycle Facility, Eden, Rockingham County, North Carolina, March 28, 2016, p. 3.
[14] NCDEQ, Air Quality Permit No. 03786T32, Facility ID: 8000004, Duke Energy Carolinas LLC, Buck Combined Cycle Facility, Salisbury, North Carolina, Rowan County, August 2, 2016, p. 3.
[15] 40 CFR 52.21(b)(23)(i) and 52.21(j)(3).
[16] EPA Combined Heat and Power Partnership, Catalog of CHP Technologies - Section 3. Technology Characterization – Combustion Turbines, March 2015, p. 15: https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies_section_3._technology_characterization_-_combustion_turbines.pdf
[17] Ibid, Table 3-2, p. 3-6 and p. 3-7.
[18] Solar Turbines, Inc., *Industrial Gas Turbine Product Line and Performance* (brochure), 2016, p. 2. Titan 250 exhaust mass flow: 541,400 lb/hr. Titan 250 fuel heat input: lower heating value (LHV) 190.8 MMBtu/hr (estimated higher heating value = 1.1 × LHV = 210 MMBtu/hr).

document to estimate a total installed cost of an SCR/oxidation catalyst/continuous emissions monitor package for the Titan 250 gas turbine of approximately $2,400,000.[19]

D. Conclusion

The NO_x emission limit proposed by Duke Energy for the 21.7 MW Duke University CHP plant is ten times greater than the NO_x emission limit of existing CHP plants using similar gas turbines at comparable universities. Duke Energy reduces the overall project cost of the Duke University CHP plant by approximately $2.4 million by avoiding the installation and use of best-in-class catalytic control systems. Duke Energy employs these best-in-class catalytic control systems on its larger gas turbine combined cycle power plants in North Carolina. Neither Duke Energy nor Duke University is precluded from voluntarily imposing best-in-class NO_x, CO, and VOC emission limits on the proposed 21.7 MW CHP plant.

[19] EPA CHP, Table 3-5, p. 3-14. Equipment cost of SCR/OxCat/CEM, 21.7 MW turbine, 90% NOx control from 15 ppm to 1.5 ppm = $1,516,400. Ratio of CHP total installed cost to equipment cost = $30,879,300 ÷ $19,397,900 = 1.59. Therefore, total installed cost of SCR/OxCat/CEM = 1.59 × $1,512,400 = $2,404,716. See **Attachment B**.

Attachment A

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE
Docket Nos. CP15-___-000
CP15-___-000
CP15-___-000

and

DOMINION TRANSMISSION, INC.
SUPPLY HEADER PROJECT
Docket No. CP15-___-000

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used only as emergency use engines. The emissions limits specified in Subpart JJJJ for emergency spark ignition engines greater than 130 hp for NOx, CO, and VOC are 2.0, 4.0, and 1.0 grams per hp-hour, respectively. Both engines have emissions guarantees that are at or below these limits.

All auxiliary generators at the ACP and SHP stations will be subject to NSPS notification and recordkeeping requirements, including records of notifications, maintenance, and documentation that the engines are certified to meet applicable emissions standards. If the engines are not certified by the manufacturer, then additional recordkeeping requirements apply.

Subpart KKKK – Standards of Performance for Stationary Gas Turbines

NSPS 40 CFR Part 60 Subpart KKKK regulates stationary combustion turbines with a heat input rating of 10 MMBtu/hr or greater that commence construction, modification, or reconstruction after February 18, 2005. Subpart KKKK limits emissions of NO_X as well as the sulfur content of fuel that is combusted from subject units.

The proposed Solar combustion turbines will be subject to the requirements of this subpart. Subpart KKKK specifies several subcategories of turbines, each with different NOx emissions limitations. All proposed turbines, except the Solar Centaur 40 turbine, fall within the "medium sized" (>50MMBtu/hr, < 850 MMBtu/hr) category for natural gas turbines. The Solar Centaur 40 turbine falls within the "small sized, mechanical drive" (< 50 MMBtu/hr) category for natural gas turbines. "Medium sized" turbines must meet a NOx limitation of 25 parts per million by volume (ppmv) at 15 percent oxygen (O_2), and "small sized, mechanical drive" turbines must meet a NOx limitation of 100 ppmv at 15 percent O_2 under the requirements of Subpart KKKK and will minimize emissions consistent with good air pollution control practices during startup, shutdown and malfunction.

Solar provides an emissions guarantee of 9 parts per million volume dry (ppmvd) NOx at 15 percent O_2 for SoLoNOx equipped units, except for the Solar Centaur 40 equipped with SoLoNOx, which has an emissions guarantee of 25 ppmvd NOx at 15 percent O_2. These guarantees apply at all times except during periods of start-up and shutdown and periods with ambient temperatures below 0°F. In addition, SCR will be installed to lower emissions for all turbines installed at the new ACP compressor Stations to further reduce NOx emissions to 5 ppmvd at 15 percent O_2, except during periods of start-up and shutdown and periods with ambient temperatures below 0°F.

The ACP and SHP compressor stations plan to conduct stack tests for NO_X emissions to demonstrate compliance with the Subpart KKKK emissions limits.

The NSPS Subpart KKKK emission standard for SO_2 is the same for all turbines, regardless of size and fuel type. All new turbines are required to meet an emission limit of 110 nanogram per joule (ng/J) (0.90 pounds [lbs]/megawatt-hr) or a sulfur limit for the fuel combusted of 0.06 lbs/MMBtu. The utilization of natural gas as fuel ensures compliance with the SO_2 standard due to the low sulfur content of pipeline quality natural gas.

Attachment B

Catalog of CHP Technologies

Section 3. Technology Characterization – Combustion Turbines

U.S. Environmental Protection Agency
Combined Heat and Power Partnership

March 2015

Table 3-5. Estimated Capital Cost for Representative Gas Turbine CHP Systems[53]

Cost Component	System				
	1	2	3	4	5
Nominal Turbine Capacity (kW)	3,510	7,520	10,680	21,730	45,607
Net Power Output (kW)	3,304	7,038	9,950	20,336	44,488
Equipment					
Combustion Turbines	$2,869,400	$4,646,000	$7,084,400	$12,242,500	$23,164,910
Electrical Equipment	$1,051,600	$1,208,200	$1,304,100	$1,490,300	$1,785,000
Fuel System	$750,400	$943,000	$1,177,300	$1,708,200	$3,675,000
Heat Recovery Steam Generators	$729,500	$860,500	$1,081,000	$1,807,100	$3,150,000
SCR, CO, and CEMS	$688,700	$943,200	$983,500	$1,516,400	$2,625,000
Building	$438,500	$395,900	$584,600	$633,400	$735,000
Total Equipment	$6,528,100	$8,996,800	$12,214,900	$19,397,900	$35,134,910
Installation					
Construction	$2,204,000	$2,931,400	$3,913,700	$6,002,200	$10,248,400
Total Installed Capital	$8,732,100	$11,928,200	$16,128,600	$25,400,100	$45,383,310
Other Costs					
Project/Construction Management	$678,100	$802,700	$1,011,600	$1,350,900	$2,306,600
Shipping	$137,600	$186,900	$251,300	$394,900	$674,300
Development Fees	$652,800	$899,700	$1,221,500	$1,939,800	$3,312,100
Project Contingency	$400,700	$496,000	$618,500	$894,200	$1,526,800
Project Financing	$238,500	$322,100	$432,700	$899,400	$2,303,500
Total Installed Cost					
Total Plant Cost	$10,839,800	$14,635,600	$19,664,200	$30,879,300	$55,506,610
Installed Cost, $/kW	$3,281	$2,080	$1,976	$1,518	$1,248

Source: Compiled by ICF from vendor-supplied data.

3.4.6 Maintenance

Non-fuel operation and maintenance (O&M) costs are presented in **Table 3-6**. These costs are based on gas turbine manufacturer estimates for service contracts, which consist of routine inspections and scheduled overhauls of the turbine generator set. Routine maintenance practices include on-line running maintenance, predictive maintenance, plotting trends, performance testing, fuel consumption, heat rate, vibration analysis, and preventive maintenance procedures. The O&M costs presented in **Table 3-6** include operating labor (distinguished between unmanned and 24 hour manned facilities) and total maintenance costs, including routine inspections and procedures and major overhauls.

[53] Combustion turbine costs are based on published specifications and package prices. Installation estimates are based on vendor cost estimation models and developer-supplied information.

Table 3-8. Gas Turbine Emissions Characteristics

Emissions Characteristics	System				
	1	2	3	4	5
Electricity Capacity (kW)	3,304	7,038	9,950	20,336	44,488
Electrical Efficiency (HHV)	24.0%	28.9%	27.3%	33.3%	36.0%
Emissions Before After-treatment					
NO_x (ppm)	25	15	15	15	15
NO_x (lb/MWh)	1.31	0.65	0.69	0.57	0.52
CO (ppmv)	50	25	25	25	25
CO (lb/MWh)	1.60	0.66	0.70	0.58	0.53
NMHC (ppm)	5	5	5	5	5
NMHC (lb/MWh)	0.09	0.08	0.08	0.07	0.06
Emissions with SCR/CO/CEMS					
NO_x (ppm)	2.5	1.5	1.5	1.5	1.5
NO_x (lb/MWh)	0.09	0.05	0.05	0.05	0.05
CO (ppmv)	5.0	2.5	2.5	2.5	2.5
CO (lb/MWh)	0.11	0.05	0.05	0.05	0.05
NMHC (ppm)	4.3	4.3	4.3	4.3	2.0
NMHC (lb/MWh)	0.08	0.06	0.07	0.06	0.02
CO_2 Emissions					
Generation CO_2 (lb/MWh)	1,667	1,381	1,460	1,201	1,110
Net CO_2 with CHP (lb/MWh)	797	666	691	641	654

Source: Compiled by ICF from vendor supplied data, includes heat recovery

Table 3-8 also shows the net CO_2 emissions after credit is taken for avoided natural gas boiler fuel. The net CO_2 emissions range from 641-797 lbs/MWh. A natural gas combined cycle power plant might have emissions in the 800-900 lb/MWh range whereas a coal power plant's CO_2 emissions would be over 2000 lb/MWh. Natural gas fired CHP from gas turbines provides savings against both alternatives.

3.5.2 Emissions Control Options

Emissions control technology for gas turbines has advanced dramatically over the last 20 years in response to technology forcing requirements that have continually lowered the acceptable emissions levels for nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOCs). When burning fuels other than natural gas, pollutants such as oxides of sulfur (SO_x) and particulate matter (PM) can be an issue. In general, SO_x emissions are greater when heavy oils are fired in the turbine. SO_x control is generally addressed by the type of fuel purchased, than by the gas turbine technology. Particulate matter is a marginally significant pollutant for gas turbines using liquid fuels. Ash and metallic additives in the fuel may contribute to PM in the exhaust.

A number of control options can be used to control emissions. Below are descriptions of these options.