Central Steam Facility: Boiler # 7 – Flames observed through the sight glass.

Chapter 4

Air Quality

Brookhaven National Laboratory (BNL) monitors both radioactive and nonradioactive emissions at several facilities on-site to ensure compliance with the requirements of the Clean Air Act (CAA). BNL also conducts ambient air monitoring to verify local air quality and detect possible environmental impacts from Laboratory operations.

During 2024, BNL facilities released a total of 22,040 curies (Ci) of short-lived radioactive gases. Oxygen-15 and Carbon-11 emitted from the Brookhaven Linac Isotope Producer (BLIP) constituted 99.9% of the site's radiological air emissions.

Because natural gas prices were comparatively lower than fuel oil prices throughout the year, BNL's Central Steam Facility (CSF) used natural gas to meet 98% of the heating and cooling needs of the Laboratory's major facilities in 2024. As a result, emissions of particulates, oxides of nitrogen, sulfur dioxide, and volatile organic compounds were well below the respective regulatory permit criteria pollutant limits.

Laboratory operations contributed to a increase in greenhouse gas (GHG) emissions due to the continued increase in commuting from 2023 to 2024 as employees return to work in-person. Commuting GHG emissions rose 24.1% as the average number of employees working on-site increased from 1,600 to 1,939 employees. In fiscal year 2024 (October 1, 2023 through September 30, 2024), air travel GHG emissions decreased by 7% to 2,716 metric tons (MT) of carbon dioxide equivalent (CO2e).

4.1 Radiological Emissions

Federal air quality laws and U.S. Department of Energy (DOE) regulations that govern the release of airborne radioactive material include 40 CFR 61: Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPs), part of the CAA, and DOE Order 458.1, Chg. 4 (DOE 2020), Radiation Protection of the Public and the Environment. Under NESHAPs Subpart H, facilities must continuously monitor emissions if they have the potential to cause an annual radiation dose greater than 0.1 mrem (1.0 µSv) to a member of the public off-site. Facilities capable of delivering radiation doses below that limit require periodic, confirmatory sampling.

BNL has two active facilities: the BLIP and the Radionuclide Research Processing Laboratory (RRPL), for which emissions are continuously monitored with in-line detection systems. BNL also has one inactive facility, the High Flux Beam Reactor (HFBR), where periodic emissions monitoring is conducted. Figure 4-1 provides the locations of these monitored facilities and Table 4-1 presents airborne release data from each facility. Annual emissions are discussed in the following sections of this chapter. The associated radiation dose estimates are presented in Table 8-5 in Chapter 8.

Table 4-1. Airborne Radionuclide Releases From Monitored Facilities.

Facility	Nuclide	Half-Life	Ci Released
HFBR	Tritium	12.3 years	2.90E-01
BLIP	C-11	20.38 minutes	7.34E+03
	O-15	122 seconds	1.47E+04
	Tritium	12.3 years	7.16E-02
RRPL	Various	Various	See Note*
Total			**2.20E+04**

Notes:
1 Ci = 3.7E+10 Bq
BLIP = Brookhaven Linac Isotope Producer
HFBR = High Flux Beam Reactor (operations were terminated in November 1999)
RRPL = Radionuclide Research Processing Laboratory
* < 1.5 µCi - No MEOSI Dose Impact (See Section 4.2.3)

Figure 4-1. Radiological and Non-Radiological Air Emission Release Points Subject to Monitoring.

4.2
Facility Monitoring

Gross alpha and beta activity emissions are monitored at the BLIP and RRPL. The BLIP's sampling point, located in the exhaust stack, is equipped with a glass-fiber filter that captures samples of airborne particulate matter released from this facility. At the RRPL, a membrane-type filter is utilized to capture samples because it is better suited to capture and detect alpha-emitting isotopes, which are the type of radionuclides predominantly being generated at the RRPL. The BLIP and RRPL filters are collected weekly by BNL personnel and analyzed by an off-site contract laboratory. The average gross alpha and beta airborne activity concentration levels for samples collected from the BLIP exhaust stack were 0.001 and 0.016 pico-curies per cubic meter (pCi/m^3), respectively. Annual average gross alpha and beta airborne activity concentration levels for samples collected from the RRPL were 0.001 and 0.006 pCi/m^3, respectively. The 2024 analytical results are summarized in Table 4-2.

Table 4-2. Gross Activity in Facility Air Particulate Filters.

Monitored Facility		Gross Alpha	Gross Beta
		—— (pCi/m^3) ——	
BLIP	N	52	52
	Max.	0.0034 ± 0.0013	0.0736 ± 0.0051
	Avg.	0.0009 ± 0.0005	0.0162 ± 0.0020
	MDL	0.0008	0.0015
RRPL - Bldg. 801	N	52	52
	Max.	0.0083 ± 0.0030	0.0357 ± 0.0073
	Avg.	0.0010 ± 0.0005	0.0055 ± 0.0013
	MDL	0.0008	0.0014

Notes:
See Figure 4-1 for monitored facility locations.
All values shown with a 95% confidence interval.
BLIP = Brookhaven Linac Isotope Producer
MDL = Minimum Detection Limit (Average of validated samples at this location)
N = Number of validated samples collected
RRPL = Radionuclide Research Processing Laboratory

4.2.1 High Flux Beam Reactor (HFBR)

The HFBR was permanently shut down in 1999. Residual tritium in water in the reactor vessel and piping systems continue to diffuse into the building's air through valve seals and other system penetrations, though emission rates are much lower than during the years of operation. In 2010, the HFBR was disconnected from the former 100-meter stack, and a new HFBR exhaust system was installed in 2011. As part of the HFBR Long-Term Surveillance Program (BNL 2023), air samples are collected from outside the HFBR confinement structure using a permanently installed sample port. Samples are analyzed for tritium to evaluate facility emissions and to ensure that air quality within the building is acceptable to permit staff entry for inspections and routine maintenance. Samples for tritium are collected over a three- or four-week collection period using a standard desiccant sampling system, and analyzed monthly by an off-site contract laboratory.

P-2 Air Monitoring Station.

4.2.2 Brookhaven LINAC Isotope Producer (BLIP)

Protons from the Liner Accelerator (LINAC) Complex are sent via an underground beam tunnel to the BLIP, where they strike various metal targets to produce new radionuclides for medical diagnostics. The activated metal targets are transferred to the RRPL in Building 801 for separation and shipment to various radiopharmaceutical research laboratories. During irradiation, the targets become hot and are cooled by a continuously recirculating water system. The cooling water also becomes activated during the process, producing secondary radionuclides. The most significant of these radionuclides are oxygen-15 (O-15, half-life: 122 seconds) and carbon-11 (C-11, half-life: 20.4 minutes). During target irradiations, both isotopes are released as gaseous, airborne emissions through the facility's 33-foot-tall stack. Emission levels of these radionuclides are dependent on the current and energy of the proton beam used to produce the radioisotopes.

In 2024, BLIP operated over a period of 39.14 weeks, during which 7,340 Ci of C-11 and 14,700 Ci of O-15 were released, totaling 22,040 Ci (see Table 4-1). In 2024, BLIP's combined emissions of C-11 and O-15 were lower than 2023 levels of 29,813 Ci. The decrease in released Curies resulted from a decrease in beam current hours and a decrease in recorded average stack flow rate. The 2024 release of tritium produced from activation of target cooling water was 0.071 Ci compared to 0.059 Ci of tritium released in 2023.

4.2.3 Radionuclide Research and Production Laboratory (RRPL)

As mentioned above in Section 4.2.2, metal targets irradiated at the BLIP are transported to the RRPL in Building 801, where isotopes are chemically extracted for radiopharmaceutical production. Airborne radionuclides released during the extraction process are drawn through a multistage high-efficiency particulate air (HEPA) and high efficiency gas adsorption (HEGA) filter system where the filtered air is then vented to the atmosphere. The types of radionuclides that are produced depend on the isotopes chemically extracted from the irradiated metal targets, which may change from year to year. Annual radionuclide quantities released from this facility are very small, typically in the microcurie (µCi) to mCi range. Historical analytical results of RRPL particulate filters have shown gross alpha/beta levels to be minimal, and the few radionuclides detected in emissions were at levels that had no impact on the potential radiological dose to members of the public, which is further explained in Chapter 8: Radiological Dose Assessment.

4.2.4 Additional Minor Sources

Several research departments at BNL use designated fume hoods for work that involves small quantities of radioactive materials in the µCi to mCi range. The work typically involves labeling chemical compounds and transferring material between containers. Due to the use of HEPA filters and activated charcoal filters, the nature of the work conducted, and the small quantities involved, these operations have a very low potential for atmospheric releases of significant quantities of radioactive materials. Compliance with NESHAPs Subpart H is demonstrated using an inventory system that utilizes upper estimates to conservatively calculate potential releases.

Facilities that demonstrate compliance using inventory methodology include Buildings 463, 490, 535, 555, 734, 745, 801, 815, and 817, where research is conducted in the fields of nuclear safety, nuclear science, biology, chemistry, high energy physics, photon science, advanced technology, environmental chemistry, and synthetic biology. Dose estimates from these facility emissions can be found in Chapter 8 on Table 8-5.

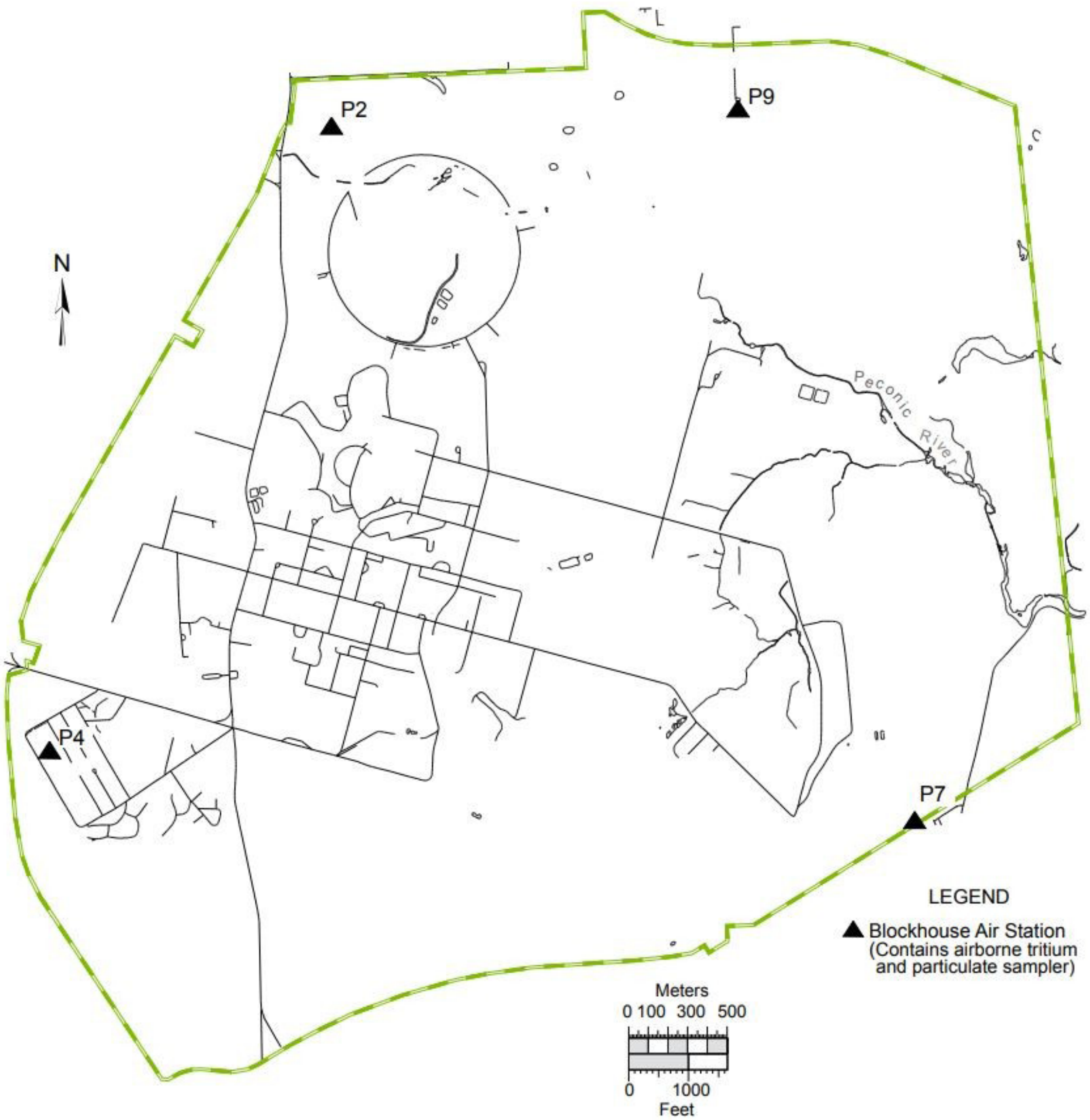
4.2.5 Nonpoint Radiological Emission Sources

Nonpoint radiological emissions from a variety of diffuse sources may be evaluated for compliance with NESHAPs Subpart H. A diffuse source is a pollution source that does not have a single identifiable point, such as a landfill or excavation. Diffuse sources are evaluated often and include planned research, planned waste management activities, and planned decontamination and decommissioning activities. Evaluations determine whether NESHAPs authorization and monitoring requirements apply, or periodic confirmatory sampling is needed to ensure compliance with Subpart H standards for radionuclide emissions.
Chapter 8 discusses the NESHAPs evaluations of diffuse sources in 2024.

4.3
Ambient Air Monitoring

As part of the Environmental Monitoring Program, air monitoring stations are in place around the perimeter of the BNL site (see Figure 4-2). There are four blockhouse stations equipped for air sampling. At each blockhouse, vacuum pumps draw air through columns where airborne particulate matter is captured on a glass-fiber filter. Particulate filters are normally collected weekly and analyzed for gross alpha and beta activity using a gas-flow proportional counter. Also, every two weeks, water vapor for tritium analysis is collected on silica-gel adsorbent material for processing by liquid scintillation analysis.

Figure 4-2. BNL On-site Ambient Air Monitoring Stations.



4.3.1 Gross Alpha and Beta Airborne Activity

Particulate filter analytical results for gross alpha and beta airborne activity are reported in Table 4-3. Ambient air samples are collected weekly from site perimeter monitoring stations P2, P4, P7, and P9. Validated samples are those not rejected due to equipment malfunction or other factors (e.g., sample air volumes were not acceptable).

In 2024, the annual average gross alpha and beta airborne activity levels for the four monitoring stations were 0.002 and 0.015 pCi/m^3, respectively. Annual gross beta activity trends recorded at Station P7 are plotted in Figure 4-3. The New York State Department of Health (NYSDOH) utilizes their own sampling equipment to collect duplicate filter samples from Station P7. These samples are collected weekly and analyzed by the NYSDOH laboratory for gross beta activity. The analytical results were comparable to the Station P7 samples analyzed by BNL's contracted lab. New York State's analytical results for gross beta activity at the Laboratory were between 0.001 and 0.017 pCi/m^3, with an average concentration of 0.008 pCi/m^3. BNL results ranged from 0.002 to 0.021 pCi/m^3, with an average concentration of 0.006 pCi/m^3.

As part of a state-wide monitoring program, NYSDOH also collects air samples in Albany, New York, a control location with no potential to be influenced by radiological facility emissions. In 2024, NYSDOH reported that airborne gross beta activity at that location varied between 0.001 and 0.026 pCi/m^3 and had an average concentration of 0.010 pCi/m^3. All of the BNL samples were less than the maximum concentration collected at the NYSDOH control location, demonstrating that on-site radiological air quality was consistent with that observed at locations in New York State not located near radiological facilities.

4.3.2 Airborne Tritium

Airborne tritium in the form of tritiated water (HTO) is monitored throughout the BNL site. In 2024, samples were collected from Stations P2, P4, P7, and P9 to assess the potential impacts from the Laboratory's two tritium sources.

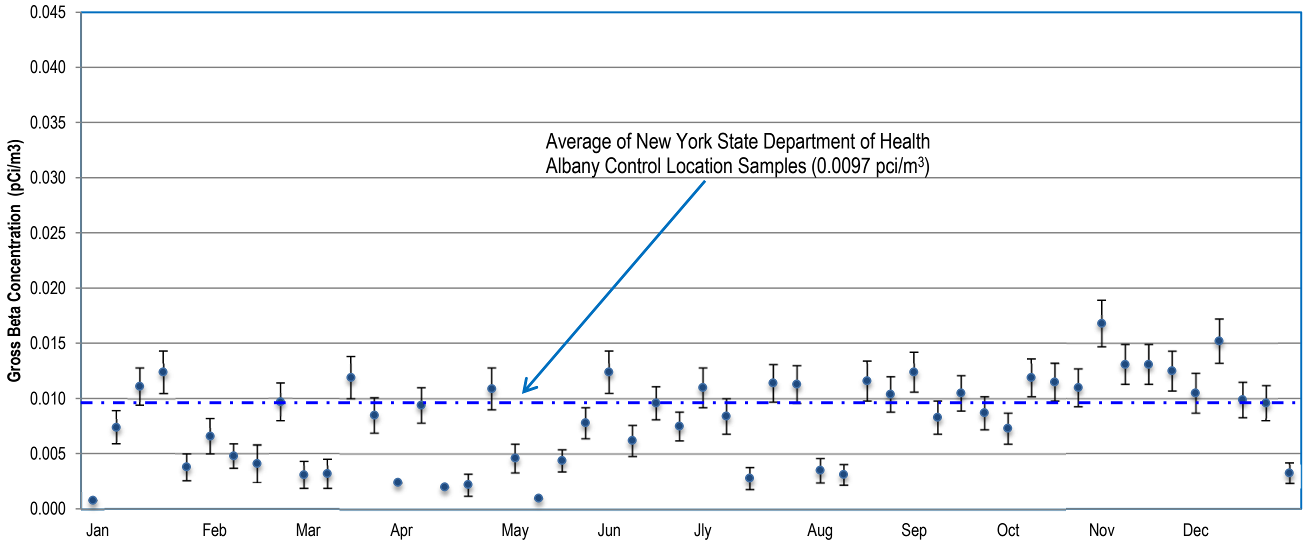
Table 4-3. Gross Activity Detected in Ambient Air Monitoring Particulate Filters.

Sample Station		Gross Alpha (pCi/m^3)	Gross Beta (pCi/m^3)
P2	N	52	52
	Max	0.003 ± 0.001	0.018 ± 0.002
	Avg.	0.001 ± 0.001	0.009 ± 0.002
	MDL*	0.0006	0.0011
P4	N	50	50
	Max	0.006 ± 0.002	0.033 ± 0.005
	Avg.	0.002 ± 0.001	0.010 ± 0.002
	MDL*	0.0007	0.0013
P7	N	52	52
	Max	0.002 ± 0.001	0.021 ± 0.002
	Avg.	0.001 ± 0.0004	0.006 ± 0.001
	MDL*	0.0004	0.0008
P9	N	50	50
	Max	0.003 ± 0.001	0.014 ± 0.002
	Avg.	0.001 ± 0.001	0.007 ± 0.001
	MDL*	0.0005	0.0010
Grand Average		**0.002 ± 0.001**	**0.015 ± 0.002**

Notes:
See Figure 4-2 for sample station locations.
All values shown with a 95% confidence interval.
MDL = Minimum Detection Limit
N = Number of validated samples collected
*Average MDL for all samples taken at this location.

Emissions at RRPL.

Figure 4-3. Airborne Gross Beta Concentration Trend Recorded at Station P7 in 2024.



Note: All values are presented with a 95% confidence interval.

Table 4-4 lists the number of validated samples collected at each location, the maximum value observed, and the annual average concentration. Validated samples are those not rejected due to equipment malfunction or other factors (e.g., a battery failure in the sampler, frozen or supersaturated silica gel, insufficient sample volumes, or the loss of sample during preparation at the contract analytical laboratory). Samples for airborne tritium were collected every two weeks from each sampling station during 2024. The average tritium concentrations at the four sampling locations ranged from 2.78 to 8.77 pCi/m^3 and were less than the contracted analytical lab's typical minimum detection limits.

Table 4-4. Ambient Airborne Tritium Measurements in 2024.

Sample Station	Wind Sector	Validated Samples	Maximum (pCi/m³)	Average (pCi/m³)
P2	NNW	25	16.50 ± 6.92	6.50 ± 3.43
P4	WSW	23	25.10 ± 14.20	7.21 ± 3.89
P7	ESE	22	19.48 ± 9.46	8.77 ± 4.36
P9	NE	25	12.9 ± 7.55	2.78 ± 1.60
Grand Average				**6.221 ± 3.27**

Notes:
See Figure 4-2 for station locations.
Wind sector is the downwind direction of the sample station from the center of the site.
All values reported with a 95% confidence interval.
Typical minimum detection limit for tritium is between 0.68 and 12.3 pCi/m^3.

4.4
Non-Radiological Airborne Emissions

Various state and federal regulations governing non-radiological releases require facilities to conduct periodic or continuous emission monitoring to demonstrate compliance with emission limits. The CSF is the only BNL facility that requires monitoring for non-radiological emissions. The Laboratory has several other emission sources subject to state and federal regulatory requirements that do not require emission monitoring (see Chapter 3 for details).

The CSF supplies steam for heating and cooling to major BNL facilities through an underground steam distribution and condensate grid. The location of the CSF is shown in Figure 4-1. The combustion units at the CSF are designated as Boilers 1A, 5, 6, and 7. Boiler 1A, which was installed in 1962, has a heat input capacity of 16.4 MW (56.7 million British thermal units per hour [MMBtu/per hour]). Boiler 5, installed in 1965, has a heat input of 65.3 MW (225 MMBtu/hr). The newest units, Boilers 6 and 7, were installed in 1984 and 1996, and each has a heat input capacity of 42.6 MW (147 MMBtu/ hr). For perspective, National Grid's Northport, New York power station has four utility-sized turbine/generator boilers, each with a maximum-rated heat input of 385 MW (1,315 MMBtu/hr).

Since the CSF boilers have the potential to emit more than 100 tons per year of oxides of nitrogen (NO_x), the CSF is considered a major facility, and all four of its boilers are subject to the Reasonably Available Control Technology (RACT) requirements of Title 6 of the New York Code, Rules, and Regulations (NYCRR) Subpart 227-2 (NYC 2019). Boilers 6 and 7 are also subject to the Federal New Source Performance Standard (40 CFR 60, Subpart Db: Standards of Performance for Industrial-Commercial-Institutional Steam Boilers) (CFR 2019) because of their design, heat inputs, and dates of installation. Both boilers are equipped with continuous emission monitoring systems (CEMS) to demonstrate compliance with the NO_x standards of these subparts, and with continuous opacity monitors to demonstrate compliance with Subpart Db opacity monitoring requirements. To measure combustion efficiency, the boilers are also monitored for carbon monoxide (CO). Following the end of each calendar quarter, facilities with boilers equipped with CEMS must tabulate and summarize emissions, monitoring, and operating parameter measurements recorded during the preceding three months. CEMS results from the two boilers are reported to the Environmental Protection Agency (EPA) and the New York State Department of Environmental Conservation (NYSDEC).

The Subpart 227-2 NO_x RACT emission limit for the combustion of natural gas and the combustion of No. 6 oil burned in the CSF three large boilers is 0.15 lbs/MMBtu. The NO_x RACT emission limit for the CSF's one mid-size boiler (Boiler 1A) is 0.20 lbs/MMBtu. From May 1 to September 30 of each year, the peak ozone period, owners and operators of boilers equipped with CEMS must demonstrate compliance with Subpart 227-2 NO_x RACT limits by calculating the 24-hour average emission rate from CEMS readings and comparing the value to the emission limit. During the remainder of the year, the calculated 30-day rolling average emission rate is used to establish compliance. Owners and operators of boilers not equipped with CEMS must demonstrate compliance with NO_x RACT limits via periodic emissions testing.

Control monitors located at CSF.

BNL uses an approved system averaging plan to demonstrate compliance in quarterly reports submitted to NYSDEC. This plan utilizes a NO_x ledger, where NO_x rate credits accumulated during quarterly periods when natural gas is burned at levels below the NO_x RACT limits offset ledger debits that may occur when fuel oil is burned. The ledger must indicate that the actual NO_x weighted average emission rate of operating boilers is less than the Subpart 227-2 permissible NO_x weighted average rate for the quarter. The actual NO_x weighted average emission rates for operating boilers in the first, second, third, and fourth quarters, respectively, were 0.150, 0.150, 0.173, and 0.150 lbs/MMBtu. The corresponding permissible weighted average emissions rates were 0.108, 0.091, 0.106, 0.095 lbs/MMBtu.

In 2024, there were two (2) six-minute average opacity readings that exceeded 27% recorded by Boiler 6 on February 28, 2024. The exceedances were due to a fuel meter/fan automatic control issue that was rectified by the operator on the same day. There were no opacity exceedances recorded by the Boiler 7 CEMS in 2024. While there are no regulatory requirements to continuously monitor opacity for Boilers 1A and 5, surveillance monitoring of visible stack emissions is a condition of BNL's Title V operating permit. Daily observations of stack gases recorded by CSF personnel throughout the year showed no visible emissions on days when the boilers were operating.

To satisfy quality assurance requirements for the continuous emissions monitoring system of the Laboratory's Title V operating permit, a relative accuracy test audit (RATA) of the Boilers 6 and 7 continuous emissions monitoring systems for NO_x and CO_2 was conducted in December 2024. The results of the RATA demonstrated that the Boiler 6 and 7 NO_x and CO_2 continuous emissions monitoring systems met RATA acceptance criteria, which are defined in 40 CFR 60, Appendix B, Specifications 2 and 3.

Fuel oil prices exceeded those of natural gas for most of the year resulting in utilizing natural gas to supply 98% of BNL's major facility heating and cooling needs. By comparison, in 2016, residual fuel satisfied 21% of the major facility heating and cooling needs. Consequently, 2024 emissions of particulates and sulfur dioxide (SO_2) were significantly less than the respective totals for 2016. Table 4-5 shows fuel use and emissions since 2014.

Table 4-5. Central Steam Facility Fuel Use and Emissions (2015–2024).

Annual Fuel Use and Fuel Heating Values							Emissions			
Year	No. 6 Oil (10^3 gals)	Heating Value (MMBtu)	No. 2 Oil (10^3 gals)	Heating Value (MMBtu)	Natural Gas (10^6 ft^3)	Heating Value (MMBtu)	TSP (tons)	NO_x (tons)	SO_2 (tons)	VOCs (tons)
2015	9.66	1,449	0.00	0	619.98	638,209	2.4	30.3	0.4	1.7
2016	804.38	120,712	0.00	0	441.98	453,348	3.7	33.6	19.0	1.7
2017	65.07	9,765	0.00	0	564.96	579,559	2.3	28.2	1.7	1.6
2018	36.04	5,409	0.04	6	642.33	662,242	2.5	31.5	1.0	1.8
2019	15.56	2,335	0.13	17.94	588.49	649,343	2.3	28.5	0.5	1.6
2020	44.20	6,455	0.00	0	553.70	610,905	2.2	28.9	1.2	1.5
2021	46.24	6,713	0.00	0	583.99	603,606	1.9	19.5	1.2	1.3
2022	342.45	49,522	40.43	5,560	567.51	587,343	2.8	36.1	8.3	1.8
2023	70.28	10,163	310.56	42,706	511.34	528,557	2.4	29.9	5.6	1.5
2024	57.31	8,288	9.82	1,350	554.14	573,502	2.2	30.8	1.4	1.5
Permit Limit (tons)							**113.3**	**159.0**	**445.0**	**39.7**

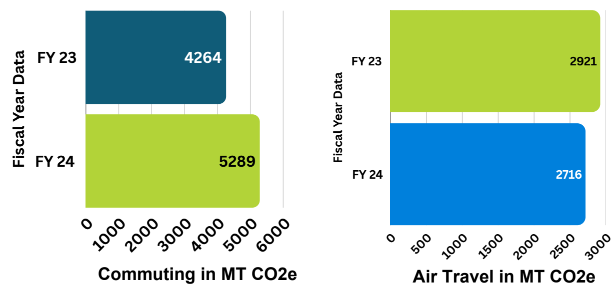
Notes:
NO_x = Oxides of Nitrogen
SO_2 = Sulfur Dioxide
TSP = Total Suspended Particulates
VOCs = Volatile Organic Compounds

4.5
Greenhouse Gas Emissions

Chapter 2 includes discussion on energy reduction efforts, which addresses BNL's approach for reducing Scope 1 and 2 GHG emissions. Please see Chapter 2 for more information. To meet the 2025 Scope 3 GHG emissions reduction goal, Scope 3 emissions must be reduced by 25% from the FY08 baseline. Overall, Scope 3 GHG emissions in 2024 increased by 1,989 MT CO2e, up 19.1% from FY23. Total emissions for FY24 are 37% less than the FY08 baseline value. The GHG emissions increase from FY23 is mainly due to an increase in employee commuting and decrease in telecommuting. Laboratory air travel and commuting GHG emissions are noted in Figure 4-4.

Figure 4-4. BNL Scope 3 Greenhouse Gases.

BNL Greenhouse Gases



2023-2024 BNL Impacts

7.0%
BNL Air Travel

24.1%
BNL Commuting

19.1%
BNL Scope 3 GHG Emissions

7.4%
BNL Telecommuting

4.5.1 Hydrofluorocarbons

In continued preparation for anticipated decreases in the availability of certain hydrofluorocarbons (HFCs) as EPA implements the HFC phasedown requirements of the American Innovation and Manufacturing Act, the Laboratory regularly examines its operations and activities that use HFCs. Regulated HFC refrigerants in existing air conditioning and refrigeration equipment account for 40% of the 45,347 pounds of refrigerants in use and have been the target of reduction efforts. Based on a review of leaks associated with Laboratory HFC refrigeration and air conditioning equipment over the last five years, current supplies of regulated HFCs are sufficient to meet anticipated future needs for system leaks.

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