Central Steam Facility.

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).

In addition, BNL conducts ambient air monitoring to verify local air quality and detect possible environmental impacts from Laboratory operations.

During 2023, BNL facilities released a total of 29,813 curies of short-lived radioactive gases. Oxygen-15 and Carbon-11 emitted from the Brookhaven Linear Particle Accelerator (LINAC) Isotope Producer (BLIP) constituted 99.9 percent of the site's radiological air emissions.

Because natural gas prices were comparatively lower than residual fuel oil prices throughout the year, BNL's Central Steam Facility (CSF) used natural gas to meet 90.9 percent of the heating and cooling needs of the Laboratory's major facilities in 2023. 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.

The Laboratory's operation under "Normal Operations with Telework," contributed to continued increases in air travel and commuting greenhouse gas (GHG) emissions from 2022 to 2023. In fiscal year 2023 (October 1, 2022 through September 30, 2023), air travel GHG emissions rose to 2,921 metric tons (MT) of carbon dioxide equivalent (CO_2e), more than two times the total of 1,247 MT CO_2e in fiscal year 2022. Commuting GHG emissions rose 23.7 percent as the average number of employees working on-site increased from 1,500 to 1,600 employees.

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, Radiation Protection of the Public and the Environment. Under NESHAPs Subpart H, facilities that have the potential to cause an annual radiation dose greater than 0.1 mrem (1.0 µSv) to a member of the public require a U.S. Environmental Protection Agency (EPA) permit and must continuously monitor emissions. Facilities capable of delivering radiation doses below that limit require periodic, confirmatory sampling.

BNL has two active facilities: BLIP and the Radionuclide Research and Production Laboratory (RRPL), whose emissions are continuously monitored with in-line detection systems, and one inactive facility, the High Flux Beam Reactor (HFBR), where continuous emissions monitoring is conducted. Figure 4-1 provides the locations of these monitored facilities and Table 4-1 presents

Table 4-1. Airborne Radionuclide Releases From Monitored Facilities

Facility	Nuclide	Half-Life	Ci Released
HFBR	Tritium	12.3 years	3.53E-01
BLIP	C-11	20.38 minutes	9.94E+03
	O-15	122 seconds	1.99E+04
	Tritium	12.3 years	5.91E-02
Total			**2.98E+04**

Notes:
1 Ci = 3.7E+10 Bq
BLIP = Brookhaven Linac Isotope Producer
HFBR = High Flux Beam Reactor (operations were terminated in November 1999)

airborne release data from these facilities. Annual emissions from monitored facilities are discussed in the following sections of this chapter. The associated radiation dose estimates are presented in Table 8-5 in Chapter 8.

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

4.2
Facility Monitoring

Radioactive emissions are monitored at the HFBR, BLIP, and RRPL. The sampling point in the exhaust stack for BLIP is equipped with a glass-fiber filter that captures samples of airborne particulate matter released from this facility. The RRPL has a membrane-type filter that is suited for the capture and detection of alpha-emitting isotopes. The filters are collected and analyzed weekly for gross alpha and beta activity. Particulate filter analytical results for gross alpha and beta activity in 2023 are reported in Table 4-2. The average gross alpha and beta airborne activity concentration levels for samples collected from the BLIP exhaust stack were 0.0003 and 0.0120 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 0.0005 and 0.0052 pCi/m^3, respectively.

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

Monitored Facility		Gross Alpha	Gross Beta
		--------(pCi/m^3)--------	
BLIP	N	39	41
	Max.	0.0015 ± 0.0011	0.0293 ± 0.0031
	Avg.	0.0003 ± 0.0005	0.0120 ± 0.0020
	MDL	0.0010*	0.0016*
"RRPL - Bldg. 801"	N	52	52
	Max.	0.0017 ± 0.0021	0.0476 ± 0.0086
	Avg.	0.0005 ± 0.0005	0.0052 ± 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
N = Number of validated samples collected
RRPL = Radionuclide Research Processing Laboratory
*Average MDL for all validated samples taken at this location

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 continued to diffuse into the building's air through valve seals and other system penetrations, though emission rates were 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 are collected for three or four weeks per month using a standard desiccant sampling system for tritium analysis. Desiccant samples are analyzed by an off-site contract laboratory.

4.2.2 Brookhaven LINAC Isotope Producer (BLIP)

Protons from the LINAC 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 2023, BLIP operated over a period of 27.1 weeks, during which 9,938 Ci of C-11 and 19,875 Ci of O-15 were released, totaling 29,813 Ci (see Table 4-1). In 2023, BLIP's combined emissions of C-11 and O-15 were higher than 2022 levels of 14,116 Ci. The increase in released Curies resulted from a 63% increase in irradiation time at maximum beam energy. The 2023 release of tritium produced from activation of target cooling water was 0.059 Ci compared to 0.042 Ci of tritium released in 2022.

Field Sampling technician checks air flow rate through sampling instruments.

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 multistage High-Efficiency Particulate Air (HEPA) and charcoal filters and 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 show gross alpha/beta levels to be minimal. As a result, there are no reported radionuclide emissions from the RRPL in Table 4-1.

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 allows an upper estimate of potential releases to be calculated.

Facilities that demonstrate compliance in this way include Buildings 463, 490, 510, 555, 734, 745, 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. See Table 8-5 in Chapter 8 for the calculated dose from these facility emissions.

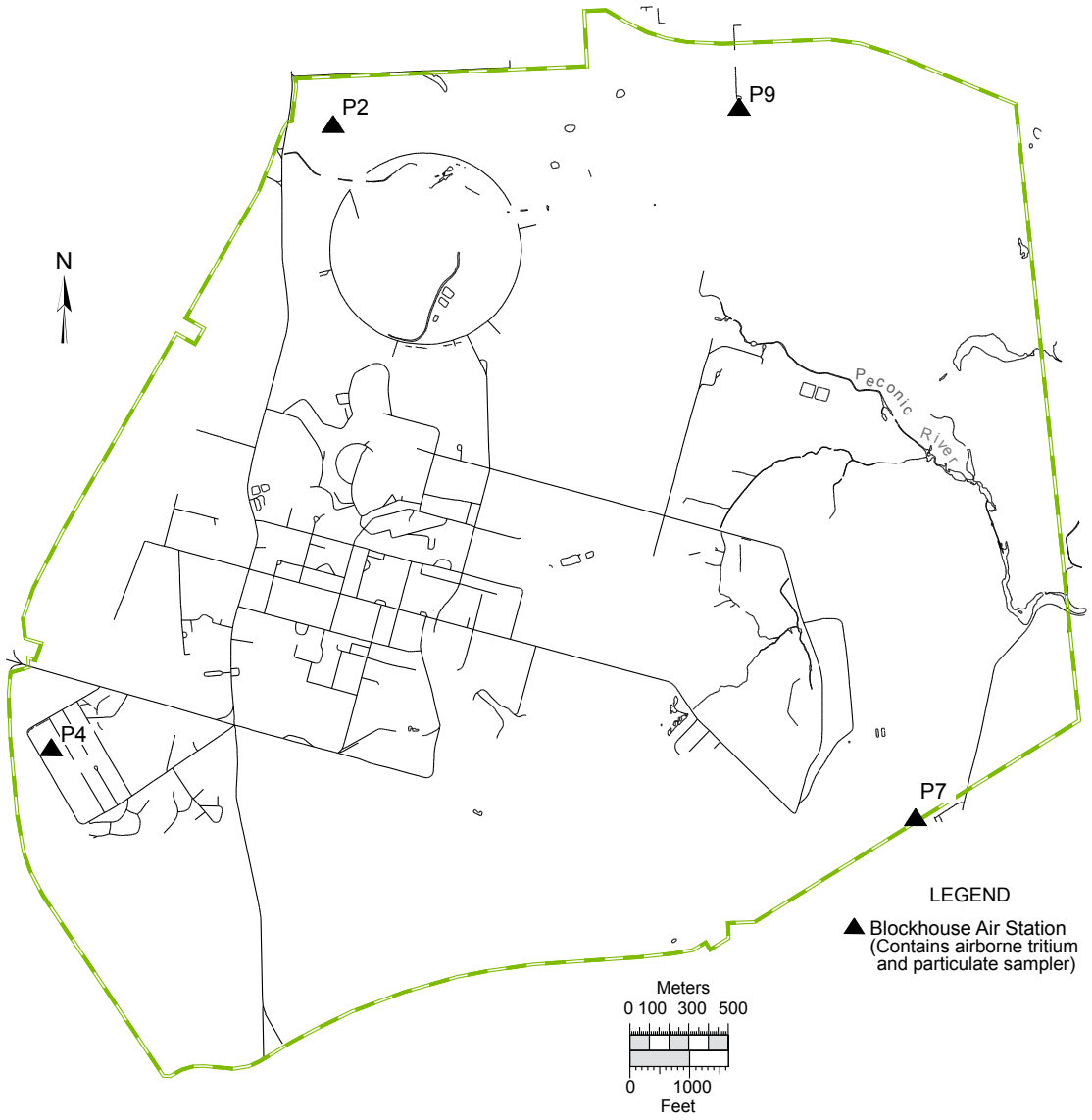
4.2.5 Nonpoint Radiological Emission Sources

Nonpoint radiological emissions from a variety of diffuse sources may be evaluated for compliance with NESHAPs Subpart H. Diffuse sources evaluated often include planned research, planned waste management activities, and planned decontamination and decommissioning activities. Evaluations determine whether NESHAPs authorization and continuous monitoring requirements are applicable, 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 2023.

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 collecting samples. 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, water vapor for tritium analysis is collected on silica-gel adsorbent material for processing by liquid scintillation analysis. Normally, these air samples are collected every two weeks. In 2023, one of the perimeter air monitoring stations was vandalized, resulting in a gap in sampling of about two months, from August 8 until October 10.

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 2023, the annual average gross alpha and beta airborne activity levels for the four monitoring stations were 0.0015 and 0.0110 pCi/m^3, respectively. Annual gross beta activity recorded at Station P7 is plotted in Figure 4-3. However, equipment problems at P7 precluded sampling from December 6, 2022 until April 11, 2023. The results for this location are typical for the site and show seasonal variation in activity within a range that is representative of natural background levels. The New York State Department of Health (NYSDOH) received duplicate filter samples that were collected at Station P7, using a sampler provided by NYSDOH. These samples were collected weekly and analyzed by the NYSDOH laboratory for gross beta activity. The analytical results were comparable to the Station P7 samples analyzed by a BNL contracted laboratory. New York State's analytical results for gross beta activity at the P7 location were between 0.0016 and 0.0309 pCi/m^3, with an average concentration of 0.0126 pCi/m^3. BNL results ranged from 0.00229 to 0.0259 pCi/m^3, with an average concentration of 0.0093 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 2023, NYSDOH reported that airborne beta concentrations at the Albany location varied between 0.0033 and 0.0387 pCi/m^3, with an average of 0.0149 pCi/m^3. Meanwhile, the airborne beta concentrations of all but two of BNL's samples at P7 were lower than the maximum concentration reported at that location. This demonstrates that BNL's on-site radiological air quality is consistent with the radiological air quality observed at locations in New York State not located near radiological facilities.

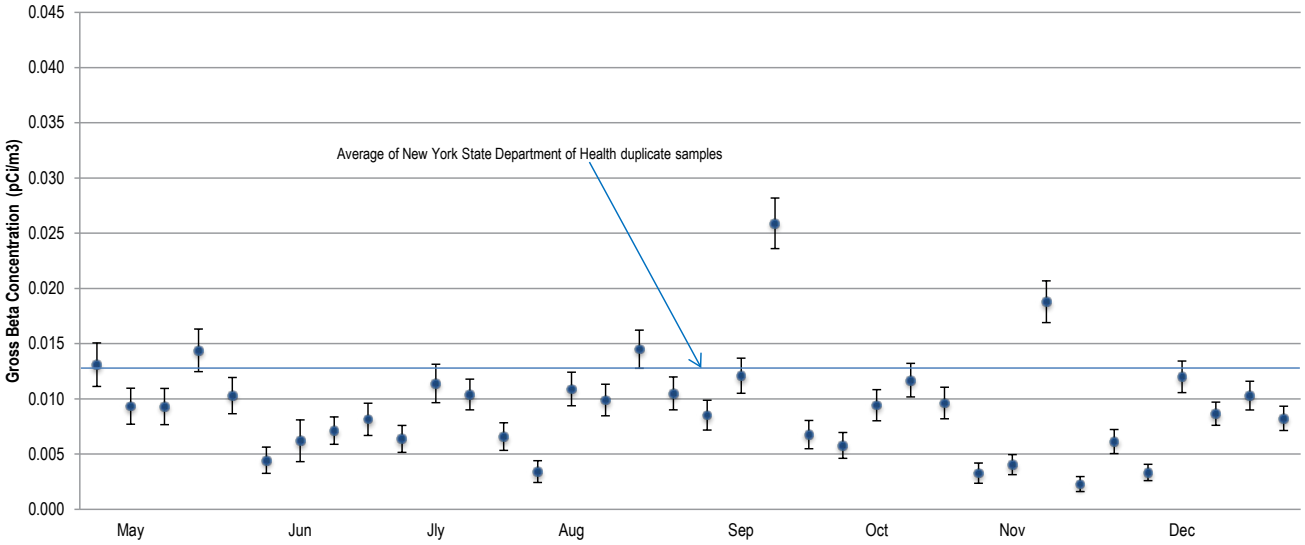
Table 4-3. Gross Activity Detected in Ambient Air Monitoring Particulate Filters.

Sample Station		Gross Alpha (pCi/m^3)	Gross Beta (pCi/m^3)
P2	N	25	40
	Max	0.0055 ± 0.0014	0.0221 ± 0.00249
	Avg.	0.0014 ± 0.0008	0.0119 ± 0.0018
	MDL	0.0008*	0.0014*
P4	N	29	51
	Max	0.0041 ± 0.0014	0.0280 ± 0.0024
	Avg.	0.0016 ± 0.0007	0.0114 ± 0.0015
	MDL	0.0006*	0.0011*
P7	N	19	36
	Max	0.0033 ± 0.0011	0.0259 ± 0.0023
	Avg.	0.0012 ± 0.0006	0.0093 ± 0.0014
	MDL	0.0006*	0.0011*
P9	N	34	47
	Max	0.0078 ± 0.0020	0.0290 ± 0.0027
		0.0016 ± 0.0007	0.0110 ± 0.0016
	MDL	0.0007*	0.0012*
Grand Average		**0.0015 ± 0.0013**	**0.0110 ± 0.0052**

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

Building P-4, one of four on-site ambient air monitoring stations at BNL (See Figure 4-2).

Figure 4-3. Airborne Gross Beta Concentration Trend Recorded at Station P7 in 2023.



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

4.3.2 Airborne Tritium

Airborne tritium in the form of tritiated water (HTO) is monitored throughout the BNL site. In 2023, samples were collected from Stations P2, P4, P7, and P9 to assess the potential impacts from the Laboratory's two tritium sources. 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 2023. The average tritium concentrations at all the sampling locations were less than the typical minimum detection limits, ranging from 0.8 to 2.9 pCi/m^3.

Table 4-4. Ambient Airborne Tritium Measurements in 2023.

Sample Station	Wind Sector	Validated Samples	Maximum (pCi/m^3)	Average (pCi/m^3)
P2	NNW	20	4.3 ± 6.1	0.8 ± 3.9
P4	WSW	24	29.1 ± 56.0	2.9 ± 8.5
P7	ESE	17	3.6 ± 9.0	0.8 ± 3.1
P9	NE	26	6.6 ± 8.1	0.8 ± 4.0
Grand Average				**1.4 ± 5.0**

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 3.5 and 12.4 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).

Because 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. Because of their design, heat inputs, and dates of installation, 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). Both boilers are equipped with continuous emission monitoring systems (CEMS) to show compliance with NO_x standards of Subpart 227-2 and Subpart Db, 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). Continuous emission monitoring results from the two boilers are reported quarterly to the (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. 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.

Since past emissions testing and CEMS results for No. 6 oil burned have shown that CSF boilers 5, 6, and 7 cannot meet the new lower NO_x RACT standards, 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 occur when Boilers 5, 6, and 7 burn oil. The ledger must show 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 0.113, 0.113, 0.096, and 0.096 lbs/MMBtu. The corresponding permissible weighted average emissions rates were 0.150 lbs/MMBtu for the first, second, and third quarters, and 0.151 lbs/MMBtu for the fourth quarter.

Fuel oil storage at the Central Steam Facility.

In 2023, it was necessary to burn remaining supplies of No. 2 oil in Tanks 5 and 6 in preparation of required internal tank inspections and to deplete fuel supplies with elevated sulfur content. A total of 310,557 gallons of No. 2 were consumed. The Laboratory purchased 80,000 gallons of ultra-low sulfur No. 2 oil for emergency purposes in September 2023.

In 2023, there were four recorded excess opacity measurements and one recorded excess NO_x measurement. The recorded excess opacity readings occurred on Boiler 7 and were due to boiler tuning or changes in boiler load. The recorded excess NO_x measurement was due to a failed fuel oil meter associated with Boiler 6. 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 operated.

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 2023. 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.

Although residual fuel prices exceeded those of natural gas for most of the year, work planning for internal tank inspections and consumption of high sulfur content No. 2 oil resulted in reducing the inventory of No. 2 and No. 6 during 2023. Regardless, natural gas was used to supply 90.9 percent of the heating and cooling needs of BNL's major facilities.

By comparison, in 2016, residual fuel satisfied 21 percent of the major facility heating and cooling needs. Consequently, 2023 emissions of particulates and sulfur dioxide (SO_2) were 1.3, and 14.4 tons less than the respective totals for 2016, when No. 6 oil was used to supply a much higher percent of site heating and cooling needs. Table 4-5 shows fuel use and emissions since 2014.

Table 4-5. Central Steam Facility Fuel Use and Emissions (2014–2023).

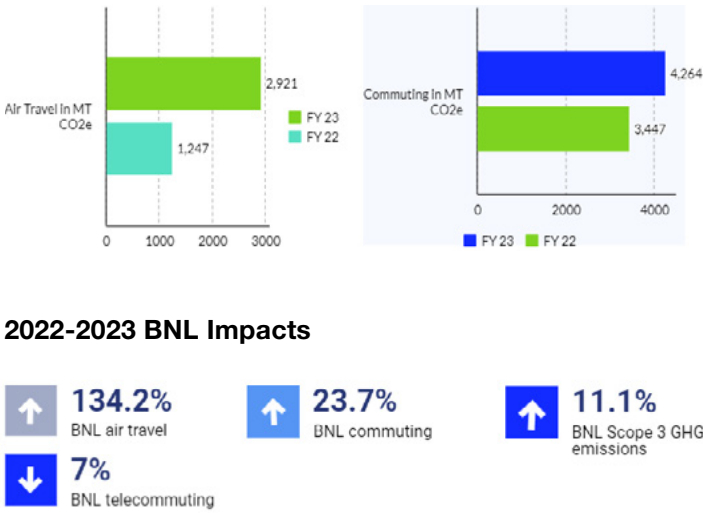
Annual Fuel Use and Fuel Heating Values							Emissions			
Year	No. 6 Oil (10^3 gals)	Heating Value (MMBtu)	No. 2 Oil (10^3 gals)	Heating Value (MMBtu)	Natural Gas (10^6 ft^3)	Heating Value (MMBtu)	TSP (tons)	NO_x (tons)	SO_2 (tons)	VOCs (tons)
2014	34.03	5,107	0	0	673.80	690,584	2.6	30.9	1.0	1.9
2015	9.66	1,449	0	0	619.98	638,209	2.4	30.3	0.4	1.7
2016	804.38	120,712	0	0	441.98	453,348	3.7	33.6	19.0	1.7
2017	65.07	9,765	0	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	0	553.70	610,905	2.2	28.9	1.2	1.5
2021	46.24	6,713	0	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	26.1	4.6	1.5
Permit Limit (in 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 an extensive discussion on energy reduction efforts, which address BNL's approach for reducing Scope 1 and 2 GHG remissions. Please see Chapter 2 for more information regarding BNL's accomplishments and challenges in this area. To meet the 2025 Scope 3 GHG emissions reduction goal, Scope 3 emissions must be reduced by 25 percent from the FY08 baseline. Overall, Scope 3 GHG emissions in FY23 increased by 1,084.6 MT CO_2e, up 11.1 percent from FY22. Total emissions for FY23 are 47.1 percent less than the FY08 baseline value. The increase from FY22 is mostly due to a 1,673.6 MT CO_2e increase in GHG emissions from business air travel, and an 816.3 MT CO_2e increase in commuting GHG emissions. Increases result from post-COVID return-to-normal activities. Laboratory air travel and commuting GHG emissions are noted in Figure 4-4.

Figure 4-4. BNL Scope 3 Greenhouse Gases: Impacts of COVID-19.



4.5.1 Hydrofluorocarbons

To prepare 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 examined its operations and activities that use HFCs. Regulated HFC refrigerants in existing air conditioning and refrigeration equipment account for 38 percent of the 43,406 pounds of refrigerants in use. 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.

References and Bibliography

40 CFR 60 Subpart Db. Standards of Performance for Industrial-Commercial-Institutional Steam Boilers, 72 FR 32742, Jun. 13, 2007, as amended by 79 FR11249, February 27, 2014.

40 CFR 61 Subpart H. National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities. 54 FR 51695, Dec. 15, 1989, as amended by 67 FR 57166, September 9, 2002.

BNL 2023, Long-Term Surveillance and Maintenance Manual for the High Flux Beam Facility, Brookhaven National Laboratory, Upton, NY. (Rev 6) September 2023.

BNL, 2023. FY 2024 Site Sustainability Plan Brookhaven National Laboratory, November 27, 2023.

DOE 2011. DOE Order 458.1. Radiation Protection of the Public and the Environment. U.S. Department of Energy, Washington, DC. Admin Chg. 4, September 15, 2020.

NYCRR Subpart 227-2, Title 6. Reasonably Available Control Technology for Oxides of Nitrogen. New York State Department of Environmental Conservation, Albany, NY., Amended November 11, 2019.

Shlein, Bernard, et al., (eds). 1998. Handbook of Health Physics and Radiological Health, Third Edition. Williams and Wilkins, Baltimore, MD.

USC Title 42, Chapter 85. Air Pollution Prevention and Control (Clean Air Act), 1990.

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