Virginia Tech Greenhouse Gas Assessment Report 2022

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Introduction

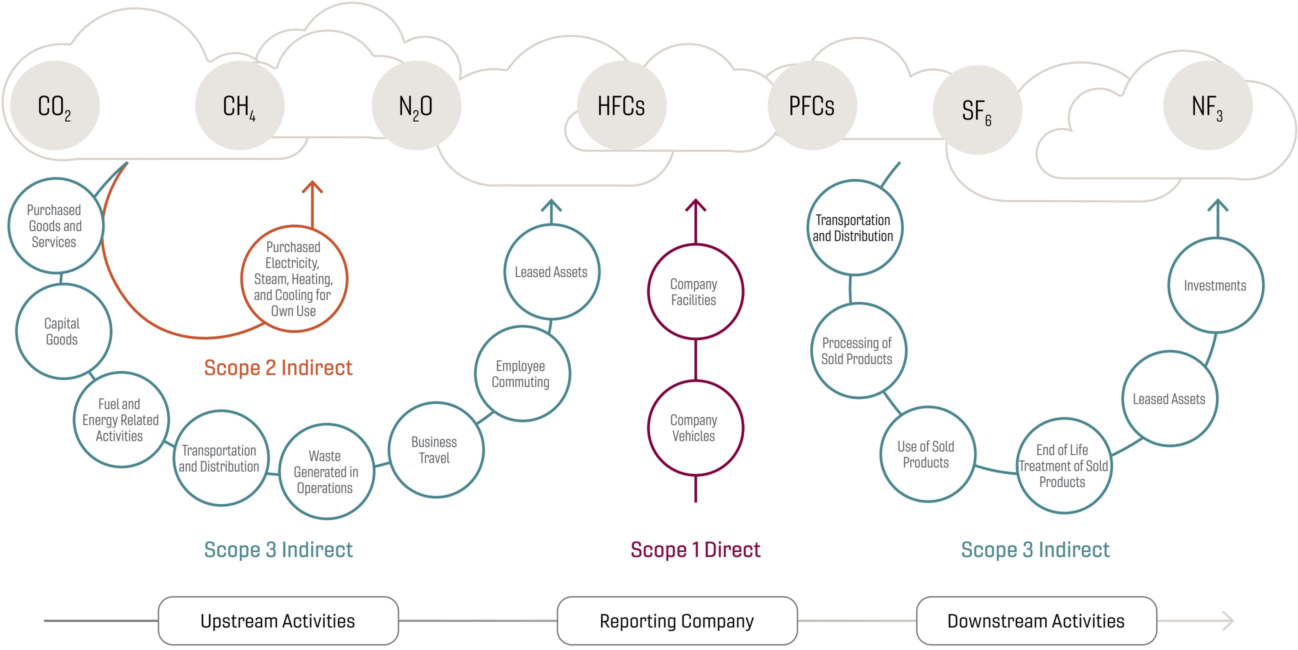
Virginia Tech has completed a Greenhouse Gas (GHG) Inventory and Assessment since 2007 as part of its Climate Action Commitment. GHGs are chemicals that absorb heat in the upper atmosphere and lead to global warming. The dominant GHG is carbon dioxide (CO_2) which emitted from the combustion of fossil fuels. Other important GHG emissions include methane (CH_4) and nitrous oxide (N_2O). These chemical quantities are compiled in a GHG assessment, often called a carbon footprint, which is a critical component of the Climate Action Commitment because it provides a quantitative analysis of the Blacksburg campus emissions and goals. It also provides a means to quantify the various sources of emissions so that detailed plans can be developed for future emissions reductions. Without an accurate GHG assessment, GHG plans and goals may not reduce emissions effectively and there can be a lack of accountability. Claims of carbon neutrality, in which all included GHG emissions are reduced to zero or offset, require a GHG assessment to confirm compliance.

The 2022 GHG assessment supports Goal 1 of the 2020 Climate Action Committee which targets a carbon-neutral Blacksburg campus by 2030. In this context, carbon neutral is defined as net-zero emissions of CO_2, CH_4, and N_2O across the Virginia Tech Blacksburg campus operations based on geographic and GHG scope defined by the 2020 Climate Action Commitment. The Climate Action Commitment resolution was approved by the University Council in November 2020 and by the Board of Visitors in March 2021.

This GHG assessment uses the Sustainability Indicator Management and Analysis Platform (SIMAP) developed by the University of New Hampshire. This is a well known GHG analysis platform used by universities around the United States. The SIMAP platform standardizes the GHG collection and accounting process, providing a more accurate and consistent analysis from year-to-year.

GHG Scope and Boundaries

Figure 1. Scope definitions for GHG assessments[1]



GHG protocols differentiate between Scope 1, 2, and 3 emissions (Figure 1). Scope 1 GHG emissions are direct emissions from owned or controlled sources like on-campus power plants, fleet vehicles, and back-up generators. Scope 2 GHG emissions are indirect emissions from the generation of purchased energy from utilities. Scope 3 GHG emissions include all other indirect emissions due to campus operations, including both upstream and downstream emissions. For universities, Scope 3 emissions can include commuting, business travel, food, waste, water, etc., but universities have more discretion in choosing which one to include in the scope boundaries. Scope 1 and 2 emissions have more rules and therefore are similar for the GHG assessments of most colleges and universities. Due to the nuances and varying methodology used to quantify Scope 3 emissions, it is difficult, and often inappropriate, to make a direct comparison among institutions.

The GHG emissions scope for the Virginia Tech assessment includes:

+ Scope 1 (emissions from campus direct fuel use),
+ Scope 2 (emissions related to purchased electricity), and
+ Some Scope 3 emissions related to the Blacksburg campus behavior (commuter miles, transit bus fuel, waste/recycling/compost, water/wastewater, aviation fuel, and commercial business travel miles), utility transmission and distribution (T&D) losses, and upstream natural gas (methane) direct leakage.

Other commonly reported Scope 3 emissions include emissions associated with campus food and sequestration of carbon dioxide by trees and land. Upstream Scope 3 emissions for dining hall food will not be included in this assessment due to the scale of the data and analysis required for accurate results. Sequestration of carbon in university forestry and agricultural lands was also not included in this assessment due to lack of data and analysis time. Both categories will be included in future assessments.

Upstream natural gas leakage is an emissions source that is rarely considered in campus GHG reports. However, these emissions sources are important to campus stakeholders based on the spring 2020 climate action surveys.

A calendar-year time scope is used in this analysis with data compiled from Jan. 1 – Dec. 31, 2022, unless specifically mentioned otherwise. This requires data from Virginia Tech from two academic and/or fiscal years (July 1 - June 30). The time frame decision was made primarily due to the calendar year time frame for emissions coefficients and renewable energy credits (RECs).

The geographic scope in this analysis includes all Virginia Tech-owned lands and buildings on the Blacksburg campus, buildings leased by university departments and the Virginia Tech Foundation in Blacksburg, and agricultural operations in the Blacksburg region. The Blacksburg campus buildings footprint is approximately 10.5 million square feet. The leased spaces, including the Virginia Tech Foundation and Corporate Research Center properties, are approximately 1.4 million square feet. The past university GHG assessments and the new scope boundaries used in the 2019-2022 assessments are listed in Table 1. Table 2 details specific scope elements for past university GHG assessments and the new scope elements for this 2022 assessment. The current GHG scope was significantly expanded in 2019.

Emissions from other Virginia Tech locations across the Commonwealth of Virginia and in other countries are not included in this assessment. Methods and protocols developed for the Virgina Tech GHG Inventory and Assessment will be shared with other university operations in the Commonwealth to help these organizations complete their own analysis.

Table 1. Comparison of past (pre-2019) and current (2022) geographical scope boundaries

Scope Boundaries	Past Scope	New Scope
Main Campus	In	In
Athletic Facilities	In	In
University Airport	In	In
Agricultural Facilities	In	In
Virginia Tech Foundry	In	In
Virginia Tech Architectural Research Building	In	In
International Campus Sites	Out	Out
Virginia Tech Carilion School of Medicine	Out	Out
Virginia Tech Leased and Foundation Properties/Buildings	Out	In
Fralin Biomedical Research Institute at Virginia Tech Carilion School of Medicine	Out	Out
Virginia Tech Roanoke Center	Out	Out
Hotel Roanoke and Conference Center	Out	Out
Agricultural Research Extension Center (ARECs)	Out	Out

Table 2. Comparison of past (pre-2019) and current (2022) scope elements

Scope Boundaries	Scope Type	Past Scope	New Scope
Coal (Steam Plant)	1	In	In
Oil (Steam Plant)	1	In	In
Natural Gas (Steam Plant)	1	In	In
Fleet Vehicles (Gasoline and Diesel)	1	In	In
Maintenance/Landscape Vehicles	1	In	In
Aviation Fuel (University Planes)	1	In	In
Diesel for Generators	1	Out	Out
Refrigerant Management	1	Out	Out
Purchased Electricity	2	In	In
Purchased Electricity T&D Losses	3	Out	In
Upstream Natural Gas Drilling/Distribution	3	Out	In
Solid Waste	3	In	In
Wastewater	3	In	In
Faculty/Staff/Student Commute	3	In	In
Dining Hall Food	3	Out	In
Compost/Landfill/Recycling	3	Out	In
Agricultural Operations (Fuel and Livestock)	3	Out	In
Agricultural Fertilizers	3	Out	In
Agriculture/Forest Land Use	3	Out	In

METHODS

Inventory data corresponding to the emissions of GHGs from the Blacksburg campus was collected from various sources at Virginia Tech and detailed in the section below. Appendix 1 summarizes the sources and contact person(s) for this data to ensure consistency from year-to-year.

University staff and faculty were used to obtain, verify, and check the data and analysis. The Division of Campus Planning, Infrastructure, and Facilities' Office of Energy Management and Office of Sustainability took the lead for this assessment.

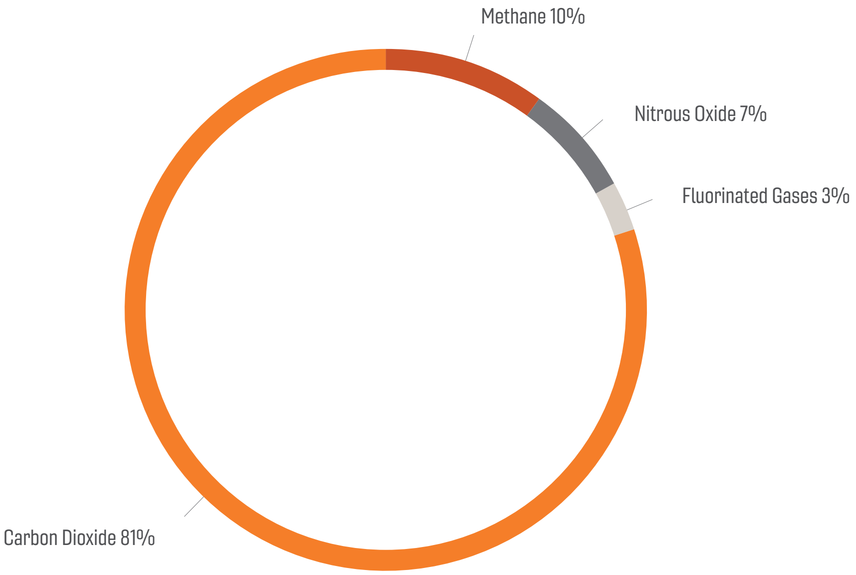
SIMAP provided the methodology for this GHG assessment. This carbon-and nitrogen-accounting platform tracks, analyzes, and informs decisions that will improve campus-wide sustainability.

GLOBAL WARMING POTENTIALS AND CARBON EMISSIONS FACTORS

Greenhouse gases (GHGs) are a class of gaseous chemicals with properties which cause them to absorb radiation and heat up the atmosphere. As shown in Figure 2, approximately 98 percent of the carbon dioxide equivalent (CO_2e) GHG emissions in the atmosphere come from carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).[2] Because CO_2 is the largest chemical contributor to overall GHG emissions both in the United States and globally, GHG emissions analyses are commonly called "carbon footprints." CO_2 is emitted to the atmosphere primarily by the combustion of fossil fuels like coal, oil, and natural gas for electricity, heating, and transportation.

Figure 2. US Greenhouse Gas Emissions (CO2e) by Chemical[2].

Rounding errors account for the fact that this chart sums to more than 100%.



This assessment considers the main GHG, carbon dioxide, as well as methane and nitrous oxide which provide additional accuracy and highlight specific emission sources like natural gas leakage, waste and wastewater decomposition, and agricultural activities related to Virginia Tech's Blacksburg campus.

In a GHG analysis, the mass of each chemical emission is multiplied by its global warming potential (GWP) per unit mass to quantify the amount of atmospheric warming that the chemical will cause based on its specific chemical properties and lifetime in the atmosphere. By definition, CO_2 is considered the baseline GHG and is given a GWP of 1.0. Chemicals with GHG values higher than one will warm the atmosphere proportionally more than an equivalent mass of CO_2 while chemicals with GHG values lower than one will warm the atmosphere less.

The GWP depends upon the time frame (number of years) under consideration due to the different lifetimes of the chemicals in the atmosphere. In this assessment, the GWPs used are 100-year potentials from the International Panel for Climate Change (IPCC) Fifth Assessment Report (AR5) shown in Figure 3.

Figure 3. IPCC AR5 Global Warming Potentials

SIMAP uses the campus inventory data including electricity (kWh), fuel (gallons), waste mass (kg), and the other data detailed in the sections that follow since CO_2 emissions are not measured directly. This inventory data was converted to GHG emissions (CO_2, CH_4, N_2O) using SIMAP default emissions factors. Customized emissions factors are noted in the report and summarized in Appendix 2. SIMAP also translates all of the emissions into carbon dioxide equivalents (CO_2e) based on the GWPs in Figure 3.

ELECTRICITY, STEAM, AND STATIONARY FUELS FOR BLACKSBURG CAMPUS

Electricity distributed by Virginia Tech Electric Service to the Blacksburg campus is purchased from Appalachian Power Company, a division of American Electric Power. Purchased electricity data (kWh) is compiled monthly by Virginia Tech's Division of Campus Planning, Infrastructure, and Facilities in a document known as the GHG Master Spreadsheet. Monthly electricity data was summed into calendar-year data for this inventory. This detailed Excel spreadsheet was used for all previous university GHG assessments.

According to the GHG Protocol Scope 2 guidance from the World Resources Institute[4], there are two recommended methods for calculating the carbon footprint for purchased electricity: location-based and market-based. For this assessment, the market-based method was used in order to accurately account for past and future renewable energy credits purchases.

Table 3. Blacksburg Campus and the Virginia Tech Power Plant Electricity Usage and Generation

Electricity Category	CY19 Electricity (kWh)	CY20 Electricity (kWh)	CY21 Electricity (kWh)	CY22 Electricity (kWh)
Education and General (E&G)	144,214,379	129,103,468	124,567,951	122,225,361
Auxiliary	63,108,898	55,027,068	59,113,525	60,006,828
Steam Plant Turbine Production	(25,785,220)	(11,748,217)	0	(19,800,181)
Total Purchased from Utility	181,537,999	172,382,319	183,681,475	162,432,008

Virginia Tech operates a university central power plant to generate steam for campus heat, hot water, and electricity needs. The Virginia Tech Power Plant uses primary fuels to generate steam used for heating buildings across campus and electricity. Currently, natural gas and a nominal amount of fuel oil are used in the boilers to generate this steam. Before being circulated for heating, this steam is typically run through a 6,250 kW turbine which generates approximately 20 million kWh annually. This electricity generation increases the thermal efficiency of the plant and is sold to Appalachian Power Company and fed into the local electrical grid for distribution. The turbine was offline from July 2020 through Feb. 2022 for repairs and refurbishment. Mar. – Dec. 2022, the turbine generated 19,800,181 kWh. In previous and future assessments, it has been assumed that all electricity produced on the Blacksburg campus is used in campus buildings. Therefore, electricity generation from the Virginia Tech Power Plant is subtracted from the total electricity usage values from Virginia Tech Electric Service to avoid double-counting electricity emissions. The utility and power plant electricity are shown in Table 3. Additionally, the 100-kW solar array on the Perry St. Garage is net-metered so the energy generation (approximately 115,000 kWh annually) is accounted for in the electric consumption data and not entered separately. The total purchased utility electricity was entered into SIMAP as a Scope 2 Emission under the category of Utility Consumption.

In terms of emissions, there are two associated emissions with electricity used for campus buildings - those from the primary fuel at the university power plant and those from the Appalachian Power Company utility fuel mix. The purchased electricity has emissions based on the Appalachian Power Company fuel mix while the Virginia Tech Power Plant electric generation emissions are calculated separately based on emissions factors for the specific power plant primary fuel inputs (oil and natural gas in 2022).

Virginia Tech Custom Electricity Emissions 2022

Custom CO_2 emissions factors were used for Appalachian Power Company utility electricity factors and are shown in Table 4. The carbon dioxide value was obtained from the Utility Specific Residual Mix Emissions Rate in the Edison

Electric Institute (EEI) Electric Company Carbon Emissions and Electricity Mix Reporting Database for Corporate Customers for 2021.[5] The 2022 carbon dioxide emissions factor is nine percent less than in 2021. The CH_4 and N_2O emissions values were not provided in the EEI database so these were taken from the EPA eGrid summary tables for 2021 for the RFCW grid region- the 2022 data was not available at the time of this report.[6]

Table 4. Utility Emissions Factors

GHG	APCO 2021 Emission Factors (lb GHG/MWh)	SIMAP 2021 Custom Emission Factors (kg GHG/kWh)	APCO 2022 Emission Factors (lb GHG/MWh)	SIMAP 2022 Custom Emission Factors (kg GHG/kWh)
Carbon Dioxide (CO_2)	1522	0.690	1384	0.628
Methane (CH_4)	0.095	0.0000431	0.095*	0.0000431
Nitrous Oxide (N_2O)	0.014	0.00000635	0.014*	0.00000635

**2021 values since updated values are not yet available from eGrid*

These factors were converted to kg GHG/kWh and entered into SIMAP under Utility Emission Factors and the source Electricity, Steam Chilled Water: Electricity in the Supplier Specific entry column. These carbon dioxide emissions factors are higher than the SIMAP default emission factors which otherwise would be based on the Reliability First Corporation West (RFCW) eGRID region data for Blacksburg, Virginia.

The Transmission and Distribution grid loss which is a Scope 3 emission was entered as a custom value of 4.5 percent in SIMAP based on eGrid 2021 data for the RFCW region.

Fuels burned in the university power plant (oil and natural gas) as well as natural gas used directly for heating buildings were entered into SIMAP as Scope 1 Emissions under the category of Stationary Fuels. SIMAP calculates the GHG emissions from the Virginia Tech Power Plant based on the fuels used in this plant as detailed in Table 5. These GHG emissions are then allocated to electricity and steam generation using two different efficiencies: the effective electricity efficiency and the total system efficiency steam efficiency as detailed on the EPA Combined Heat and Power website.[7] These efficiencies were calculated by Virgina Tech's Division of Campus Planning, Infrastructure, and Facilities' Engineering Services team. Fuel amounts were converted to energy (MMBtu) for SIMAP using the following energy densities: 26.5 MMBtu/ton for coal (average values from coal heat input), 138,000 Btu/gallon for oil (low sulfur), and 1.035 MMBtu/MCF for natural gas (energy density from Atmos Energy, the natural gas provider). Note that the university master spreadsheet used a natural gas density of 1.027 MMBtu/MCF up until July 2020.

Table 5. Virginia Tech Stationary Fuel Usage

Stationary Fuels	2019	2020	2021	2022
Coal (VT Steam Plant - Short Tons)	8,835	2,162	0	0
Oil (VT Steam Plant - Gallons)	3,600	14,622	11,150	16,838
Natural Gas (VT Steam Plant - MMBtu)	1,005,236	1,009,530	1,015,091	1,125,701
E&G and Auxiliary Building Natural Gas (Buildings - MMBtu)	130,955	122,477	118,557	112,048

**Estimate based on 2019 data*

RENEWABLE ENERGY CREDITS

No renewable energy credits were purchased in 2022 in contrast to the 90,220 Appalachian Power Company hydropower renewable energy credits (55,405 MWh) purchased for the 2019 GHG assessment. Each renewable energy credit offsets the emissions associated with one MWh of purchased electricity. If this equivalent amount of renewable energy credit offsets were purchased in 2022, the net MTCDE would be reduced 14 percent.

VIRGINIA TECH BLACKSBURG LEASED SPACE

Virginia Tech leases space in buildings, both on the Blacksburg campus and off campus in the Town of Blacksburg. This makes collection of energy usage data more difficult. Even though this space is not owned or controlled by the university, it does contribute directly to university operations. Therefore, the associated emissions were included in the scope.

Leased-space data included electricity and natural gas usage for these buildings. Real Estate Management provided the majority of data, along with the support of Melissa Wrenn at the Virginia Tech Electric Service. This additional scope adds 41 leased-space buildings with approximately 1.4 million square feet of space. This includes prominent buildings like the Math Emporium, the Virginia Tech Transportation Institute, Kent Square, the University Gateway Center, the North End Center, and several buildings in the Corporate Research Center.

Utility data availability varies due to collection processes. Natural gas account data for leased spaces is collected by the Real Estate Management Office in the CAC Data Collection spreadsheet. In Jan. – Dec. 2022, natural gas data was provided for 11 rental/leased buildings. The electricity data was also provided by Real Estate Management in the CAC Data Collection spreadsheet, as well as from monthly spreadsheets provided by Virginia Tech Electric Service and titled Electric Rental Accounts. For the accounts provided by Virginia Tech Electric Service, the electricity bills were adjusted given the assumption that Virginia Tech occupies, on average, 60 percent of the space in these buildings.

These estimated consumption values are shown in Table 6.

Table 6. Leased Space Energy Usage

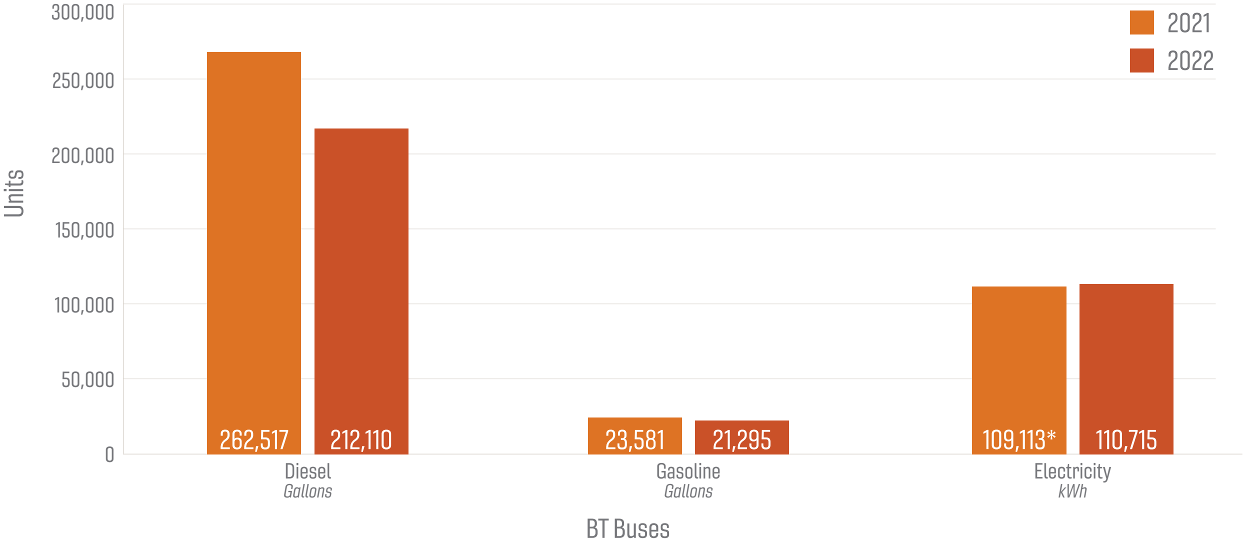
Leased Space Utility Consumption Source	2019	2020	2021	2022	Units
Electricity	38,429,092	32,664,729	36,881,742	40,208,790	kWh
Natural Gas	23,744	23,744	7,409	3,367	MMBtu

TRANSPORTATION

Transportation emissions in the scope of this assessment include the Blacksburg Transit bus system fuels, commuting miles for faculty/staff/students, university fleet fuels, agricultural operation fuels, Air Transportation Services fuels, and university business airline passenger miles from trips booked through travel agencies. Out of

Figure 4. Blacksburg Transit Bus System Fuels

**Data is April - December 2021*



scope for this assessment, mainly due to lack of data, are emissions from university business airline trips purchased by individuals and departments without travel agencies, student/faculty study abroad travel, and non-commuter student travel to/from their permanent homes at the start/end of the semester or on breaks/weekends.

GHG emissions from the Blacksburg Transit bus system were included based on direct fuel use provided from Tim Witten at Blacksburg Transit. SIMAP generally calculates commuter emissions based on passenger-miles, but the direct fuel gallons from Blacksburg Transit are both easier to obtain and more accurate than passenger-mile bus emission estimates. The bus fuel data is shown in Figure 4 and based only on "revenue fuel," which is fuel directly used for the transit system. Electricity for the electric buses, put into service in 2021, is included in this analysis and counted as a Scope 2 emissions, in contrast to most transportation emissions which are considered as Scope 3. The direct fuel values were entered in SIMAP as Transport Fuels but re-classified as Scope 3 emissions in line with GHG protocols. There is currently no easy or accurate way to separate student, faculty, staff, and town resident bus trips so all bus fuel and electricity was attributed to Virginia Tech in this assessment. This is likely a slight overestimate of emissions since a very small portion of bus trips are related to town residents rather than campus activities.

Commuter Results

GHG emissions for commuters are difficult to estimate since neither miles driven nor fuel usage data is available for all student, staff, and faculty commuters from their residences to campus. Since surveys only capture the information for a fraction of all commuters, the university GHG commuter estimates were based on both permit data from the Virginia Tech Transportation Services and a spring 2023 campus survey. This survey was much more detailed and accurate compared to the survey used for the 2019 and 2021 GHG Analysis and Report.

The number of permits sold by Virginia Tech in academic year 2022-2023 is used as a proxy for number of commuters in different categories in Table 8. This data includes 92 different permit categories and is summarized in Appendix 4. This analysis cover 92 percent of the 24,444 permits sold for that academic year.

Table 8. Virginia Tech Parking Permit Summary Data

vt.edu/about/facts-about-virginia-tech

Enrollment	Total	Enrollment	Total
Undergraduate Student	80%	Faculty	18%
Graduate Student	20%	Staff	82%
Total	37,000	Total	13,000

SIMAP Commute Category	Survey Responses	# of Commuters	Commuting Weeks/Yr	1-Way Trip/Week	Vehicles Miles/Trip	Total Vehicle Miles/Yr
Faculty*	815	957	42.8	8.6	10.7	3,770,237
Staff	871	4,228	46.2	8.4	14.9	24,448,081
Graduate Student*	220	1,208	40.4	9.1	8.8	3,906,960
Undergraduate Student*	328	4,831	25.9	9.7	3.3	4,004,783
Undergraduate Resident	338	2,804	17.0	4.8	1.9	434,686
"No Permit" Undergraduate Students**	289	7,249	21.3	7.2	2.9	3,223,819
Total	2,861	21,276	—	—	—	39,788,565
Weighted Student Parameters	—	16,091	30.0	8.0	3.0	11,585,200
Actual VMT Estimate from VT Survey and Permit Data						11,570,248

*Daily Permits added by dividing by days in Commuting Weeks

** Undergraduate population - Undergrad Permits* % undergrad responses without permit (33%)

The number of commuting weeks/year, one-way trips/week, and vehicle miles/trip were taken from an analysis of the spring 2023 survey of faculty, staff, and students with 2,861 responses. The total responses, in the table below is approximately 10 percent of the number of campus permits so the data is relatively robust for using averages. The specific relevant questions (14 – 16) for this analysis are shown in Appendix 5. The commuter survey has some limitations, but overall the responses provided good average values to be used for the different commuter permit groups. Approximately five percent of the survey responses were modified for this analysis since the values were clearly typographical errors, misunderstandings, or another problem which made the data unsuitable for the analysis.

For this GHG report, permits are categorized as Faculty/Staff (F/S), Commuter/Graduate (C/G) and Resident. SIMAP separates out faculty and staff and the survey found differences for graduate student travel characteristics compared to undergraduate. Therefore, total number of Virginia Tech employees and students and the percent breakdown at the top of the table was used for estimation purposes.

The total vehicle-miles-traveled (VMT) estimate for 2022 compared to 2019 is 20 percent less. Much is this estimated reduction is due to fewer faculty-staff permits which directly impact the VMT estimate.

From this data, the following analysis methodology was used to estimate commuting passenger-miles for SIMAP. For each commuter category, the number of commuters estimated by the purchased permit passes was multiplied by the number of estimated driving weeks for that permit and multiplied by the number of one-way trips/week and multiplied by the number of VMT per trip to get the total VMT per year. All trips were considered single passenger trips since we have limited data to estimate carpooling, but expect this assumption does not significantly affect the final estimates.

SIMAP default emissions factors per passenger-mile were used for all commuting estimates. Only automobile trips were entered into the SIMAP Commuting category at 100 percent since bus trips were accounted for in Transport Fuels as discussed above and Virginia Tech has no other significant powered commuting options that lead to GHGs. Data was obtained in the survey for the percentage of commuting trips such as walking, biking, and bussing, but this data is not reported here.

The survey data indicates:

Staff > Faculty > Graduate Student > Undergraduate Commuter > Residential
Trip Distances

The residential undergraduate trip distance (1.9 miles) was greater than the parking area to most spots on campus and likely due to errors in the respondents distance estimates. The number of commuting weeks and number of trips per week per category were distributed as expected:

Staff > Faculty > Graduate Student > Undergraduate
Commuting Weeks

A small number of daily permits were included as single trips by dividing the permits by averaging commuting weeks multiplied by five days per week. Graduate and undergraduate student number of trips per week were greater than faculty and staff who tend to come and go from campus about a bit more than four days per week on average.

Approximately 33 percent of undergraduate drivers indicated in the survey that they did not purchase a permit but still drove occasionally (7.2 one-way trips per week). We interpreted this to mean that their trips were one of the following:

1. drop-offs which don't require a parking permit but were anecdotally said by students to be common,
2. trips to campus using parking meters or daily passes, or
3. trips to campus after parking-enforcement hours at night and on weekends.

Given this large number of self-reported "no permit" students who commuted regularly, these miles were included and estimated as follows. No-permit commuters were estimated as 33 percent of the difference between the total undergraduate enrollment minus the number of undergraduate Commuter plus Resident permits.

Undergraduate commuting data for Resident, Commuter, and No-Permit students was combined together under Student Commuting. Weighted values were used for weeks/permit, trips/week, and miles/trip were since SIMAP does not allow for different parameters for each of these student commuter type and our survey indicated significant differences between the groups. These weighted values entered into SIMAP are shown in the last table and seen to be very close to the estimate using the separate categories.

Figure 5. University Commuter Survey Results (GHG MTCDE)

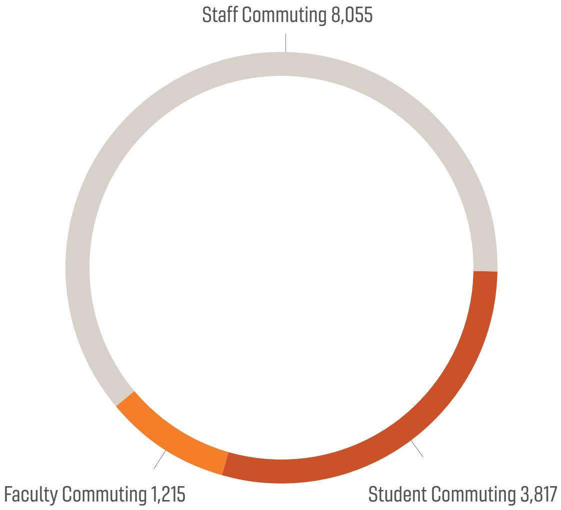


Figure 6. Virgina Tech Transport Fuels (Gallons)

Transport Fuels are listed in Figure 6 and were entered in SIMAP under Scope 1 Transport Fuels. This includes Fleet Services, Agricultural Operations, and Aviation Fuels. Data from Fleet Services fuel pumps were compiled from the Virginia Tech master spreadsheet. This data represents the fuel purchased from Fleet Services fuel pumps for all university fleet vehicles or any departmentally-owned vehicles. For long-distance trips or vehicles off campus, fuel can be purchased on fuel cards or with personal credit cards. This card-purchased fuel data was not available and there is no current mechanism to capture it so these Fleet Fuel values are under-estimates. Capturing the off-campus fuel purchases is recommended as a goal for future assessments.

Fuels for Agricultural Operations were provided by various College of Agriculture and Life Sciences department contacts. In cases where data was not provided for facilities, estimates based on 2019 data were used. The contacts are listed in Appendix 7, College of Agriculture and Life Sciences department contacts.

Aviation fuels (Jet Fuel A) were compiled by the Virgina Tech Air Transportation Services. This data included fuel purchased locally at the Montgomery County Airport and destination airports. The university planes are co-owned by Virgina Tech and a non-university group in Roanoke. Fuel data was split and only reported for Virgina Tech flights. Custom emissions factors for Jet Fuel A were entered into SIMAP from an EPA Emission Factors for GHG Inventories data sheet.[8] Note that the carbon dioxide emission coefficient for Jet Fuel A was multiplied by a radiative forcing factor of 2.7 to account for the stronger effect on climate change due to the specific nature and chemistry of airline emissions at higher elevations in the atmosphere.[9] This additional factor is automatically multiplied by the emissions factor in SIMAP.

Airline Travel Analysis

The business travel scope in this 2022 assessment is limited to the fleet fuel data in the section above and airline travel. The airline data is complex and partially incomplete since different faculty and staff use different methods to book airline flights and this impacts the ability to compile the data. Airline travel booked on personal credit cards or through departments without using a travel agency could not be obtained easily so the GHG assessment for this category is an underestimate. Better methods for capturing all airline travel, independent of booking method, will be considered for the future.

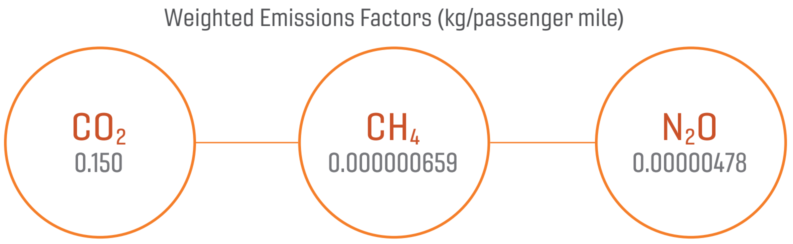
Airline travel data for trips booked through the three primary university-approved travel agencies (AAA Corporate Travel, Covington Travel, and Anthony Travel for Athletics) for calendar year 2022 was obtained from Lynn Meadows, from the Virginia Tech Controller's Office. For each agency and trip, city pairs (the starting and ending city) and the mileage between them was provided. These city-pair miles were summed and then sorted into long (≥2,300 miles), medium (≥300 and <2,300 miles) and short haul flights (<300 miles) based on the EPA carbon emissions factors shown in Table 9 Scope 3 Category 6: Business Travel and Category 7: Employee Commuting from the 2022 EPA Center for Corporate Climate Leadership GHG Emission Factors Hub[10].

Table 9. EPA Climate Leadership Hub with 2022 Airline Emission Factors

Vehicle Type	CO_2 Factor (kg/unit)	CH_4 Factor (g/unit)	N20 Factor (g/unit)	Units
Air Travel - Short Haul (<300 miles)	0.207	0.0064	0.0066	passenger-mile
Air Travel - Medium Haul (≥ 300– <2300 miles)	0.129	0.0006	0.0041	passenger-mile
Air Travel - Long Haul (≥ 2300 miles)	0.163	0.0006	0.0052	passenger-mile

SIMAP uses a single set of CO_2, CH_4, and N_2O carbon emissions factors for airline flights. To use the more accurate EPA data based on flight distance from Table 9, a weighted-average custom factor was calculated for this data. The total CO_2, CH_4, and N_2O emissions (kg) for Virgina Tech airline travel were determined for long, medium and short haul flight distances using the appropriate EPA carbon emission factors. These total carbon emissions by chemical were then summed and divided by the total number of flight miles to provide the set of custom CO_2, CH_4,and N_2O emission factors (kg/passenger mile) shown in Figure 7 for SIMAP. The details for these weighted factors are provided in Appendix 6.

Figure 7. Weighted Airline Emissions Factors using EPA data



**Does not include 2.7 radiative force emissions factor*

SOLID WASTE & WASTEWATER

Municipal solid waste (MSW) and wastewater data came from the GHG master spreadsheet. All of Virginia Tech's municipal solid waste goes to a landfill in Dublin, Virginia, and methane is recovered from the landfill to generate electricity. In 2022, Virginia Tech produced 4,590 tons of municipal solid waste. This data was entered in SIMAP in the Waste & Wastewater category as Solid Waste: Landfilled Waste: CH_4 Recovery and Electric Generation which gives GHG credit for the avoided emissions due to the electricity generation. There were no compost operations in 2022.

In 2022, the university sent 516,645,201 gallons of wastewater to the Blacksburg Water Authority. This wastewater is processed on the wet end of the treatment process by an aeration system consisting of biological nutrient removal and de-nitrification. The de-nitrification process has anoxic and anaerobic zones. For the sludge-handling process, there are two autothermal thermophilic aerobic digesters and one storage nitrification de-nitrification reactor which is mainly for the removal of ammonia. This wastewater was entered into SIMAP as Wastewater: Central Treatment System - Aerobic.

Table 10. Virginia Tech Waste and Wastewater

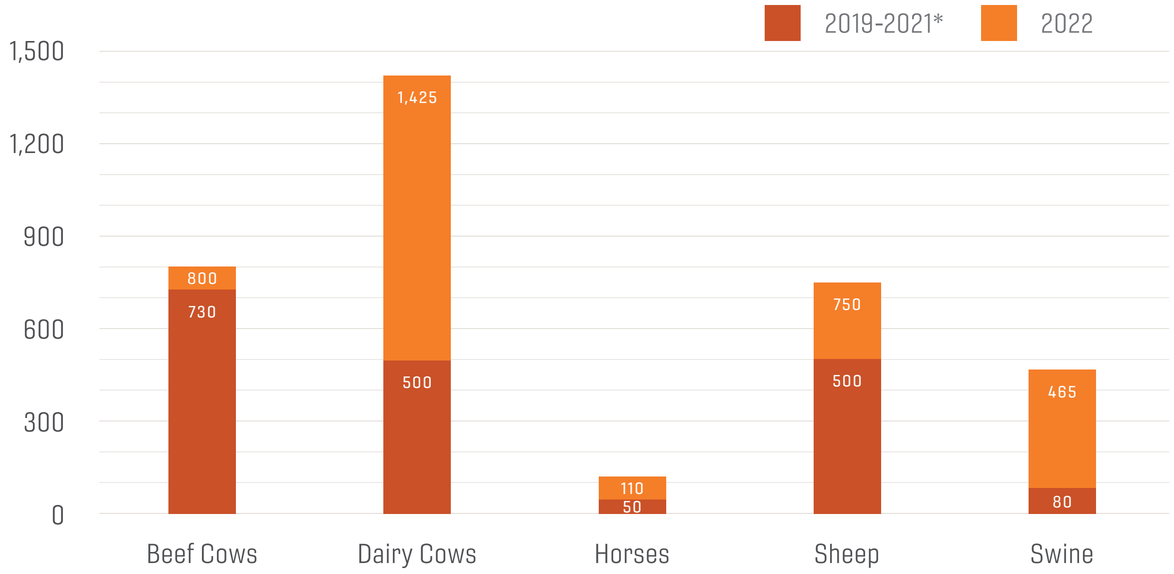
Year	Total MSW Produced (tons)	Total Wastewater Produced (gallons)
2019	3,937	461,610,000
2020	2,597	512,620,000
2021	3,510	556,819,167
2022	4,590	516,645,201

AGRICULTURAL OPERATIONS: FERTILIZER, LIVESTOCK, AND LAND USE

Virgina Tech has agricultural operations on the Blacksburg campus which includes the use of land, the management of animals, and the growth of crops. Emissions from animals were calculated both for the animal digestive process (enteric fermentation) and their manure based on the numbers of each type of livestock in Figure 8.

Fertilizer applied on university agricultural lands is a Scope 1 emission. Nitrogen from the fertilizer oxidizes to volatile N_2O. There are different types of fertilizer that are applied at Virgina Tech as shown in Table 13. Liquid and solid applied manure data was provided in kilogallons and tons, respectively, along with Total Kjeldahl Nitrogen (TKN) values. The TKN values were converted to percent nitrogen with a density of 8.5 lb/gallon assumed for the liquid manure. The percent nitrogen for the synthetic fertilizer and animal manure was assumed from common values in the literature.

Figure 8. Virginia Tech Agricultural Animals



**Data was only provided for 2019. These values were used as estimates in the 2021 inventory*

Virgina Tech compiles fertilizer data based on total nitrogen mass while SIMAP requires total fertilizer mass and percent nitrogen. From the percent nitrogen and total nitrogen university data, the Total Fertilizer Mass for the fertilizers was back-calculated. The SIMAP default emissions factor was used for the nitrogen to N_2O conversion. Fertilizer and animals contribute approximately 4.2 percent of the total university GHG emissions, more than the categories of commuting, buses, fleet fuels, or business air travel.

Table 11. Agriculture Operation Fertilizer Analysis

Fertilizer Type	TKN	Total N (lb)	%N in Fertilizer	Total Fertilizer Mass (lb) 2019-2021*	Total Fertilizer Mass (lb) 2022
Applied Liquid Dairy Manure	8.3lb/kgal	24,402	0.098%	24,990,000	29,968,280
Applied Liquid Swine Manure	1.85lb/kgal	2,017	0.022%	9,265,000	11,568,000
Applied Solid Dairy Manure	8.9lb/ton	23,861	0.445%	5,362,000	4,360,000
Applied Solid Mixed Animal Manure	12.36lb/ton	10,630	0.618%	1,720,000	1,200,000
Applied Synthetic Fertilizer	N/A	36,060	46%	78,391	56,173
Cattle Manure (land droppings)	N/A	230,299	3%	7,676,633	16,112,925
Sheep/Horse Manure (land droppings)	N/A	16,279	3%	542,633	247,875

**Data was only provided for 2019. These values were used as estimates in the 2021 inventory*

Methane Leakage Analysis

Methane, the main component of natural gas, is a potent greenhouse gas with a GWP of 28 over a 100 year time scale. Natural gas is often discussed as a bridge fuel with lower GHG emissions compared to coal, but this is true when considering only the combustion of the fuels. Including the leakage of natural gas across its lifecycle, from mining to processing to distribution, leads to a higher overall carbon footprint of this fuel. Reports in the literature suggest that natural gas leakage in the range of three percent cause the life-cycle GHG emissions of natural gas to be comparable to those for coal.[10] Including this GHG emission source in the updated Virginia Tech Climate Action Plan was a major request by the Virginia Tech Climate Justice group whose activities on campus raised awareness of climate change issues and led to an updated Climate Action Plan. This emission source is not reported by most organizations in their GHG assessments, but it is similar to the electricity upstream transmission and distribution (T&D) losses which are typically reported in Scope 3.

The GHG emissions and methane leakage due to upstream operations associated specifically with natural gas use at Virginia Tech is not available, but scientific estimates of the average system leakage rates are available in the scientific literature. An analysis in 2018 estimated the total methane leakage rate from the oil and natural gas supply chain at 2.3 percent with 95 percent of the leakage data between 2.0 - 2.7 percent.[12] Another recent synthesis article on methane emissions for the natural gas supply chain, production through distribution, and found that 1.7 percent of the methane in natural gas is emitted between extraction and delivery with 95 percent of the leakage data between 1.3 and 2.7 percent.[13]

Based on these and other recent articles, we applied the current SIMAP default of 2.3 percent leakage to natural gas used by the Virginia Tech Power Plant, buildings and leased spaces. This is slightly higher than the 2.0 percent value used in previous years. The primary natural gas used by the utility to generate electricity for Virginia Tech was also included by considering the 26 percent natural gas in the Appalachian Power Company 2022 fuel mix from the EEI database[14], an estimated utility power plant efficiency of 35 percent and a T&D loss of 4.5 percent. The resulting leakage estimate was entered into SIMAP as a Scope 1 emission under the refrigerants and chemicals category. These emissions were manually adjusted to Scope 3 emissions per GHG protocols. A summary of these results in shown in Table 12 while the detailed calculations are shown in the Appendix.

SIMAP has recently updated in Scope 3 emissions to include Fuel and Energy-Related Activities (FERA). This category includes upstream emissions of purchased fuels, upstream emissions for purchased electricity, and T&D losses. Our natural gas leakage estimate consists of some, but not all, of the emissions. The FERA emissions will be reported separately this year, but not in the totals for 2022 since they weren't in the baseline or previous reports.

Table 12. Virgina Tech Natural Gas Leakage Estimate

Upstream Methane Leakage Estimate	Value	Units	Comments
Natural Gas Leak Rate	2.3%	—	SIMAP Average leak rate based on 2 more recent scientific articles
Virginia Tech Direct Natural Gas	34,849,434	m^3	—
Virginia Tech Indirect Natural Gas from Electricity	14,722,419	m^3	—
Methane Leakage	1,140,153	m^3	—
Natural Gas Mass Density[15]	0.700	kg/m^3	unitrove.com/engineering/tools.gas/natural-gas-density @ 20C, 1 atm
Total Natural Gas Mass Leakage	798,107	kg	—
Natural Gas Mass Leakage	1,759,826	lb	value with SIMAP entry units

Upstream Methane Leakage Estimate	2019	2021	2022
Natural Gas Leak Rate (From Literature)	2.0%	2.0%	2.3%
VT Natural Gas (m^3)	31,977,085	31,218,459	34,849,434
VT Indirect Natural Gas (from Utility Electricity) (m^3)	12,416,295	12,948,387	14,722,419
Natural Gas Leakage (m^3)	887,868	883,337	798,107
Natural Gas Mass Density (kg/m^3)	0.70	0.70	0.70
Total Methane Mass Leakage (lb)	**1,370,424**	**1,363,431**	**1,759,826**

Results and Discussion

All GHG emissions results were calculated by SIMAP based on the inventory data and emissions factors detailed in the previous sections. The units MTCDE are metric tons carbon dioxide equivalent. The resulting emissions are shown in Table 13, 14, and in the pie-chart of Figure 9.

Table 13. SIMAP GHG Emissions Results

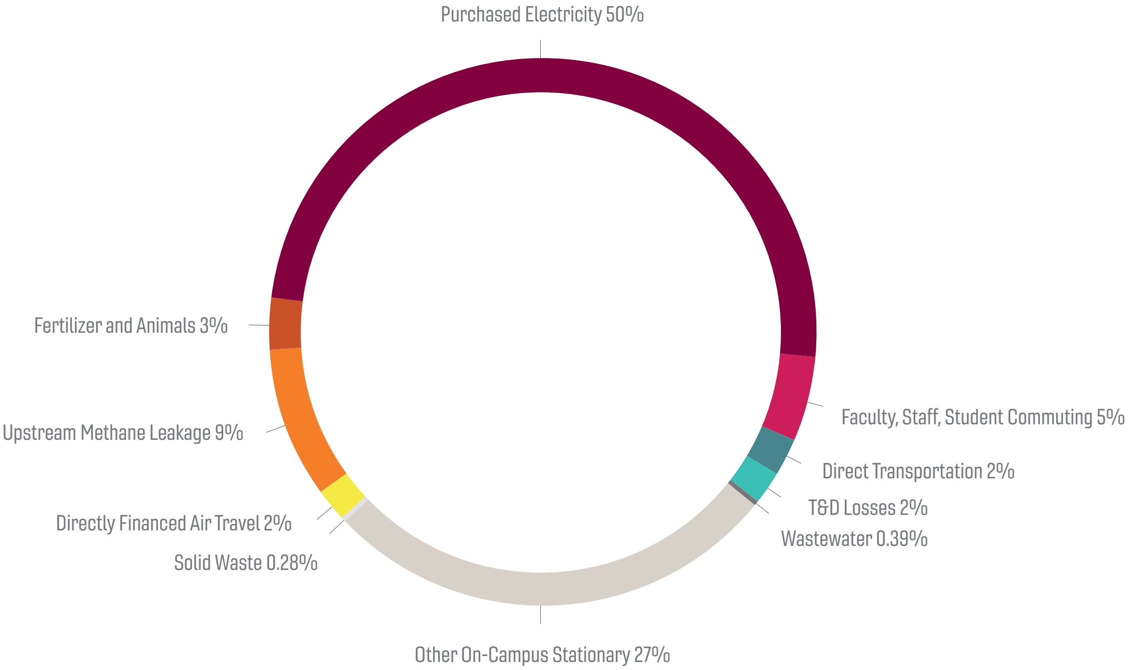
Scope	Source	CO_2 (kg)	CO2 (MTCDE)	CH4 (kg)	CH4 (MTCDE)	N2O (kg)	N2O (MTCDE)	GHG (MTCDE)	GHG (% Annual Total)
1	Other On-Campus Stationary	67,923,262	67,923	6,780	190	137	36	68,149	26.5%
1	Fertilizer and Animals			166,519	4,663	7,041	1,866	6,528	2.5%
1	Direct Transportation	5,563,373	5,563	82	2	56	15	5,581	2.2%
2	Purchased Electricity	127,327,950	127,328	7,909	221	1,104	292	127,842	49.7%
3	Faculty, Staff, Student, Commuting	12,971,948	12,972	708	20	459	122	13,113	5.1%
3	T&D Losses	5,999,746	6,000	373	10	52	14	6,024	2.3%
3	Directly Financed Air Travel	6,096,192	6,096	10	0	72	19	6,116	2.4%
3	Wastewater	—	—	9,238	259	2,847	754	1,013	0.4%
3	Solid Waste	—	—	25,704	720	—	—	720	0.3%
3	Upstream Methane Leakage	—	—	—	—	—	—	22,351	8.7%

Table 14. SIMAP GHG Emissions by Scope

Scope 1	Scope 2	Scope 3
31%	50%	19%
80,258 MTCDE	127,842 MTCDE	49,336

Total 257,437 MTCDE

Figure 9. SIMAP Virginia Tech 2022 GHG Emissions by Category



The total estimated GHG emissions for this assessment are 257,437 metric tons CO_2e. This is 10 percent lower than the emissions of 2021. The direct university emissions in Scope 1 account for 31 percent. The Scope 2 emissions account for 50 percent of the GHG emissions. The indirect emissions of Scope 3 are 19 percent of the total carbon footprint.

Breaking this down by GHG chemical, 88 percent of these emissions are due to CO_2, 11 percent due to CH_4, and one percent due to N_2O. From a source perspective, 76 percent of the emissions results from operations and building energy from the utilities and the Virginia Tech Power Plant. The emissions associated with losses due to electricity and natural gas distribution are 11 percent and not under the control of the university, though these values scale down linearly as energy use is reduced. Transportation fuels account for approximately 10 percent of emissions and half of these emissions are attributed to faculty/staff/student individual car commuting. Reducing vehicle usage can easily and cost effectively reduce these emissions, as well as through more efficient vehicles. The expected transition in the future to more electric vehicles will mainly move these emissions from the fuels to the electricity category, but emissions are expected to continue to drop in the future due to higher electric vehicle efficiencies and more renewable energy in the electrical grid.

For context, Figure 10 shows previous Virginia Tech GHG assessment results. 2019 is the start of the baseline year and all prior results shouldn't be directly compared given the significant changes in the method and the expanded scope of this assessment. The main changes in 2019 are adding leased building space, the BT bus system, renewable energy credits, business air travel, electricity T&D losses, and methane leakage. CH_4 and N_2O GHG emissions were also not considered in past assessments prior to 2019. Despite these scope additions, the total GHG emissions in 2019 were only approximately 20 percent higher than estimated in 2018 mainly due to the hydropower renewable energy credits which reduced the overall electricity emissions.

Figure 10. Past Virginia Tech Calendar Year GHG Assessments

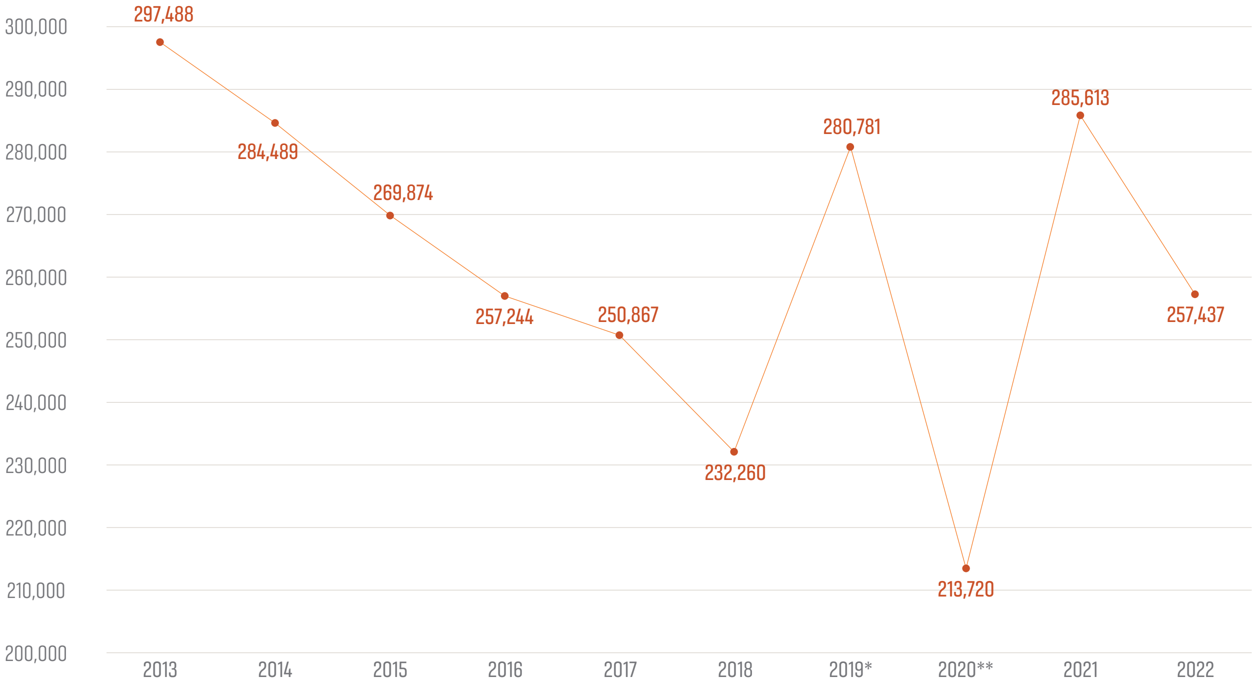
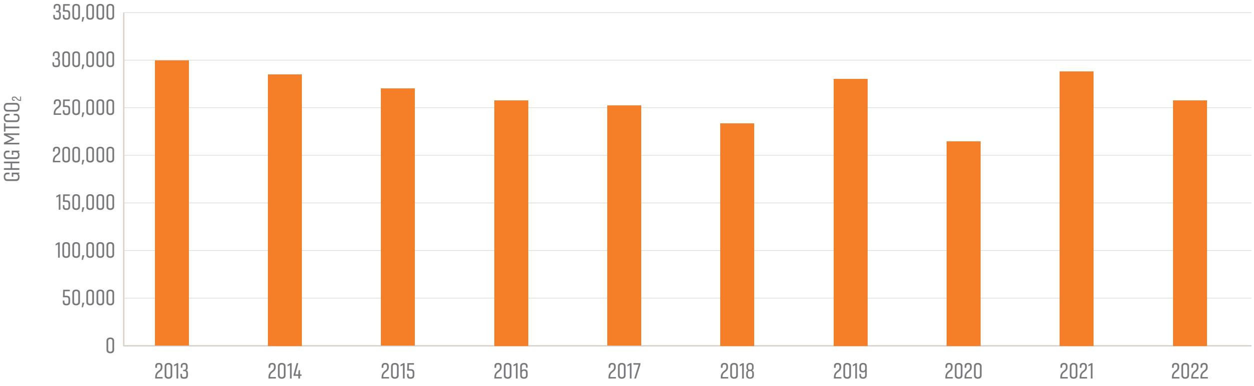


Figure 11. Annual GHG Assessment Total



Conclusions

The 2022 Virginia Tech GHG emissions assessment was completed during the summer 2023 using the expanded scope and methods recommended by the GHG subcommittee of the spring 2020 climate action committee. All recommended scope elements are included in this assessment except for dining/food emissions and carbon sequestration by Virginia Tech agricultural/forestry lands and the campus tree canopy. This report is a critical piece of the Virginia Tech Climate Action Plan since it provides detailed data for future decisions and plans to reduce carbon emissions associated with Virginia Tech.

A future project is recommended to determine the best way to handle and analyze the large amount of dining/food data which is available from Dining Services to estimate upstream food emissions. Carbon sequestration due to Virginia Tech campus lands in Blacksburg also need to be considered in the future.

References

[1] World Resources Institute (WRI) and the World Business Council for Sustainable Development, GHG Protocol FAQ, ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf

[2] US Environmental Protection Agency (EPA), Inventory of U.S. Greenhouse Gas Emissions and sinksepa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

[3] GHG Protocol Website, Global Warming Potential Values, ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

[4] World Resources Institute (WRI), GHG Protocol FAQ, GHG Protocol Scope 2 Guidance, ghgprotocol.org/sites/default/files/ghgp/standards/Scope%202%20Guidance_Final_0.pdf

[5] Edison Electric Institute, Electric Company Carbon Emissions and Electricity Mix Reporting Database for Corporate Customers, June 2022, Appalachian Power Company WV/VA, eei.org/en/issues-and-policy/national-corporate-customers/co2-emission

[6] US Environmental Protection Agency (EPA), Emissions & Generation Resource Integrated Database (eGRID), eGrid Summary Tables, 2020, epa.gov/egrid

[7] US Environmental Protection Agency (EPA), Methods for Calculating CHP Efficiency website, epa.gov/chp/methods-calculating-chp-efficiency

[8] US Environmental Protection Agency (EPA), Emission Factors for GHG Inventories data sheet, April 2014, epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

[9] Lee, D. S., et al. "The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018." Atmospheric Environment 244 (2020): 117834.

[10] Emission Factors for Greenhouse Gas Inventories, last modified March 26, 2020, Table 10, Center for Corporate Climate Leadership GHG Emission Factors Hub, EPA Center for Corporate Climate Leadership website, Table 10, Scope 3 Category 6: Business Travel and Category 7: Employee Commuting, epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

[11] Howarth, Robert W. "A bridge to nowhere: methane emissions and the greenhouse gas footpring of natural gas." Energy Science & Engineering 2.2 (2014): 47-60.

[12] Alvarez, Ramón A., et al. "Assessment of methane emissions from the US oil and gas supply chain." Science 361.6398 (2018): 186-188.

[13] Littlefield, James A., et al. "Synthesis of recent ground-level methane emission measurements from the US natural gas supply chain." Journal of cleaner production 148 (2017): 118-126.

[14] Electric Company Carbon Emissions and Electricity Mix Reporting Database for Corporate Customers, Edison Electric Institute (EEI), July 2020, aepsustainability.com/performance/esg-reports/

[15] Unitrove Natural Gas Density Calculator, unitrove.com/engineering/tools/gas/natural-gas-density

Appendices

Appendix 1: Virginia Tech GHG Data Source Summary Table

Category	Data Source	Contact Person and Info	Comments
Blacksburg Campus Electricity, Natural Gas, and Steam Plant Fuels	Virginia Tech Division of Campus Planning, Infrastructure, and Facilities Master Spreadsheet	**Simona Fried*,** simonaf@vt.edu Manager of Energy Projects and Analytics, Office of Energy Management **Todd Robertson,** phrobert@vt.edu Associate Director Utilities, Power Plant **David Sciarretta,** dsciarre@vt.edu Power Plant Operations Support Supervisor **Melissa Wrenn,** wrenma@vt.edu Business Manager, Virginia Tech Electric Service **Mai George,** mai.george@atmosenergy.com Revenue Systems Analyst, Atmos Energy Corporation **Wesley Gibson,** gwesley7@vt.edu Engineering-Controls Tech, Virginia Tech Electric Service	—
Electricity Emission Factors	Appalachian Power Company direct contact	**William Rogers,** wrogers@aep.com Customer Account Manager **Sean McGinnis,** smcginn@vt.edu	Emissions factor values for 2022
Renewable Energy Credits (RECs)	Virginia Tech Electric Service	**Rob Glenn,** robglenn@vt.edu Director of Electrical Services, Virginia Tech Electric Service	Source for 2019 RECs
Fleet Fuels	VT Fleet Services	**Anthony Dove,** anthd69@vt.edu Fleet Operations Coordinator, VT Fleet Services	Only fuels dispensed at Fleet Services
Aviation Fuels	VT Air Transportation Services	**Melissa Ball,** mlball@vt.edu Flight Operations Manager	—
Transit Bus Fuels	Blacksburg Transit (BT)	**Tim Witten,** twitten@blacksburg.gov Blacksburg Transit	—
Commuting Permits and Fuels	Virginia Tech Transportation Services Commuter Survey	**Nick Quint*,** nquint@vt.edu Transportation Network Manager, Alternative Transportation **Sean McGinnis,** smcginn@vt.edu	—
Airline Travel	Airline City Pair Spreadsheets	**Lynn Meadows,** dlynnm06@vt.edu Senior Travel Consultant, University Controller	Data only for travel agency airline bookings
Solid Waste	VT Master Spreadsheet	**Teresa Sweeney,** msrecycle247@vt.edu Waste and Recycling Manager, Grounds	—
Wastewater	VT Master Spreadsheet	**Suzanne Miller,** sem0616@vt.edu Fiscal Technician, Facilities Business Office **Michael Vaught,** vaughtbvpisa@aol.com Executive Director, Blacksburg-VPI Sanitation Authority	—
Compost	VT Office of Sustainability	**Nathan King*,** naking@vt.edu Sustainability Manager, Office of Sustainability	—
Water	VT Master Spreadsheet	**Caleb Taylor,** ctaylor@nrvwater.org Executive Director, NRV Regional Water Authority	—
Fertilizer, Animals, and Agriculture Fuel	Manure Spreadsheet and College of Agriculture and Life Sciences direct contacts	**Clint Steger,** jasteger@vt.edu Agricultural Manager **Patrick Hilt,** philt@vt.edu Director of College Facilities, CALS Research	—

** The asterisk identifies the primary contact for the data.*

Appendix 2: SIMAP 2022 Custom Emissions Factors

Version	Scope	Source	Emission Type	EF	Units
2022	1	Direct Transportation Sources: University Fleet: Other (Liquid Fuels)	CH_4	0.000001	kilogram/US gallon
2022	3	Directly Financed Outsourced Travel: Air-Faculty/ Staff	CH_4	0.000001	kilogram/passenger mile
2022	1	Direct Transportation Sources: University Fleet: Other (Liquid Fuels)	CO_2	26.325	kilogram/US gallon
2022	3	Directly Financed Outsourced Travel: Air-Faculty/ Staff	CO_2	0.150000	kilogram/passenger mile
2022	1	Direct Transportation Sources: University Fleet: Other (Liquid Fuels)	N_2O	0.0003	kilogram/US gallon
2022	3	Directly Financed Outsourced Travel: Air-Faculty/ Staff	N_2O	0.000005	kilogram/passenger mile

Appendix 3: Virginia Tech Permit Data

Permit Type	Count
AA Year Hangtag	16
AA 30 Year Employee	3
Faculty/Staff Motorcycle - Replacement	1
Faculty/Staff Motorcycle With Hangtag	47
Faculty/Staff Motorcycle - Year	5
Faculty/Staff Hangtag - 30 Year Employee	419
Faculty/Staff Hangtag - 30 Year Employee - Spring	20
Faculty/Staff Hangtag - Year	4074
Faculty/Staff Hangtag - Fall	109
Faculty/Staff Hangtag - Spring	414
Faculty/Staff Hangtag - Summer	18
Faculty/Staff Wage - Monthly	388
Faculty/Staff Wage - Quarterly	67
New Employee Permit	358
Faculty/Staff Remote - Year	235
Faculty/Staff Remote - Replacement	2
Faculty/Staff Hangtag - Remote Spring	55
Carpool Student Hangtag - Year	62
Carpool Student Hangtag - Fall	12
Carpool Student Hangtag - Spring	9
Faculty/Staff Carpool Hangtag - Fall	153
Commuter Hangtag - Perry St.	845
Graduate Hangtag - Perry St.	301
Resident Advisor Hangtag	83
Resident Advisor Hangtag - Spring	18
Resident Motorcycle - Year	5
Resident Motorcycle with Hangtag - Spring	1
Resident Motorcycle - Fall	1
Resident Hangtag -Year	1680
Resident Hangtag -Fall	380
Resident Hangtag - Spring	887
Resident Hangtag - Summer	33
Student - Remote	25

Permit Type	Count
Commuter Hangtag - Year	2928
Commuter Permit - Replacement	6
Commuter Motorcycle with Hangtag	13
Commuter Motorcycle with Hangtag - Spring	1
Commuter Motorcycle - Year	23
Commuter Motorcycle - Fall	8
Commuter Hangtag - Fall	935
Commuter Hangtag - Spring	633
Commuter Hangtag - Summer	380
Graduate Motorcycle with Hangtag	15
Graduate Motorcycle	5
Graduate Motorcycle - Fall	1
Graduate Hangtag - Year	819
Graduate - Replacement	2
Graduate Hangtag - Fall	136
Oak Lane Hangtag - Year	325
Oak Lane Hangtag - Fall	88
Faculty/Staff Hangtag - Evening Only	24
Faculty/Staff - Evening Only - Semester	12
Student - Evening Only	674
Student - Evening Only - Semester	551
Visitor - Evening Only	5
Visitor - Evening Only - Semester	5
Commuter/Graduate - Daily	1204
Commuter/Graduate - Perry St. - Daily	625
Faculty/Staff - Daily	176
Faculty/Staff - Daily (Excludes North End Garage)	1900
Perry St - Daily	1
Student - Daily	68
Resident - Daily	1713
Visitor - Daily	54
Overnight Parking	11
Multi-Day Permits	164
Total	**24,444**

Appendix 4: Virginia Tech Transportation Survey Questions used for the Commuter Analysis

Question 14 – During a typical year, approximately how many weeks will you drive to campus? (subtract out times you use non-driving modes and weeks during breaks, vacation, etc. when you're not commuting)
Question 15 – On average, how many one-way trips from home to campus or campus to home will you take in a typical week? To clarify, driving to campus and back home counts as two (2) trips. Include multiple trips in the same day in your estimate.
Question 16 – What is your average commute distance from your primary residence to your first destination on campus?

Appendix 5: Natural Gas Analysis Summary for Methane Leakage Analysis

Inputs			Comments
Source	**Value**	**Units**	
CY 22 Natural Gas Consumption			
Power Plant	1,125,701	MCF	Data from Virginia Tech Facilities Master Spreadsheet converted from MMBtu using 1.035 MMBtu/MCF
Buildings	101,743	MCF	Updated from Leased Space natural gas data
Leased Space	3,253	MCF	—
Total Campus	1,230,697	MCF	
	34,849,434	m3	35.3147 ft2=1m3
CY22 Purchased Electricity Consumption			
APCO Electricity (Campus)	132,432,008	kWh	Data from Virginia Tech Facilities Master Spreadsheet
APCO (Leased Space)	40,208,790	kWH	Data from Leased Space
Electric Bus Electricity (BT)	110,715	—	Electric buses implemented in April 2021
Total APCO Electricity	202,751,513	kWh	—
PP efficiency	35%		Power plant efficiency assumption
T&D Loss	4.5%		T&D loss from eGRID 2021 (2022 data currently not available)
NG Primary Fuel (input)	606,586,425	kWh	
NG Primary Fuel Percentage	26%		APCO NG% fuel mix from APCO 2022 Utility Specific Fuel Mix in EEI Database1
NG Primary Electricity Share	157,712,471	kWh	—
NG Primary Energy Input	538,115	MMBtu	Energy conversion from kWh to MMBtu
NG Energy Density	1.035	MMBtu/MCF	Energy Density from Atmos
NG Volume	519,918	MCF	—
Indirect Natural Gas for Electricity	14,722,419	m3	35.3147ft3=1m3
Total NG	49,571,854	m3	

Upstream Methane Leakage Estimate	Value	Units	Comments
Natural Gas Leak Rate	2.3%		SIMAP Average leak rate based on two more recent scientific articles 2,3
Virginia Tech Direct Natural Gas	34,849,434	m3	
Virginia Tech Indirect Natural Gas from Electricity	14,722,419	m3	
Methane Leakage	1,140,153	m3	
Natural Gas Mass Density	0.700	kg/m3	unitrove.com/engineering/tools/gas/natural-gas-density @ 20C, 1atm
Total Natural Gas Mass Leakage	798,107	kg	
Natural Gas Mass Leakage	1,759,826	lg	Value with SIMAP entry units
GWP Factor	28		IPCC AR5 technical report
GHG Emissions	22,346,992	kg CO_2-eq	
Total	24,638	tCO_2-eq	

[1] Electric Company Carbon Emissions and Electricity Mix Reporting Database for Corporate Customers, Edison Electric Institute (EEI), June 2022, aepsustainability.com/performance/esg-reports

[2] Burns & Grubert 2021. Attribution of production-stage methane emissions to assess spatial variability in the climate intensity of US natural gas consumption. Environmental Research Letters 16: doi.org/10.1088/1748-9326/abef33

[3] Omara et al. 2018. Methane Emissions from Natural Gas Production Sites in the United States: Data Synthesis and National Estimate. Environmental Science & Technology 52: 12915 - 12925.

Appendix 6: Airline Travel Analysis Summary for Custom Emissions Factors

	Long	Medium	Short	Totals
AAA	7,896,038	3,864,334	24,799	11,785,171
Covington	700,317	351,196	589	1,052,102
Anthony (Athletics)	397,101	1,689,055	128,897	2,215,053
	8,993,456	5,904,585	154,285	15,052,326

EPA Emission Factors (Table 10)

	CO_2 kg/unit	CH_4 g/unit	N_2O g/unit
Long	0.163	0.0006	0.0052
Medium	0.129	0.0006	0.0041
Short	0.207	0.0064	0.0066

Airline miles multiplied by EPA Emissions Factors to get Total Emissions

Emissions (kg)				
Type	CO_2	CH_4	N_2O	Totals
Long	1465933	5.40	46.77	1465985
Medium	761691	3.54	24.21	761719
Short	31937	0.99	1.02	31939
Total	2259562	9.9	72	2259644

Total emissions per chemical divided by total miles to get custom average emissions factor to yse in SIMAP along with the total passenger miles

Weighted Emission Factors (kg/passenger mile)			
Chemical	CO_2	CH_4	N_2O
Custom Factors	0.150	0.000000659	0.00000478

Appendix 7 – Agriculture Department Contacts

Department/Unit	Contacts
Turf Grass Center	John Hinson Tetyana Early
Kentland SPES	Brooks Saville Tetyana Early
Greenhouse	Jeff Burr Tetyana Early
BSE	Laura Lehman Dwayne Edwards
Crop Production	Clint Steger
Animal Science	Clint Steger
Dairy	Clint Steger
Biochem	Pete Kenelly