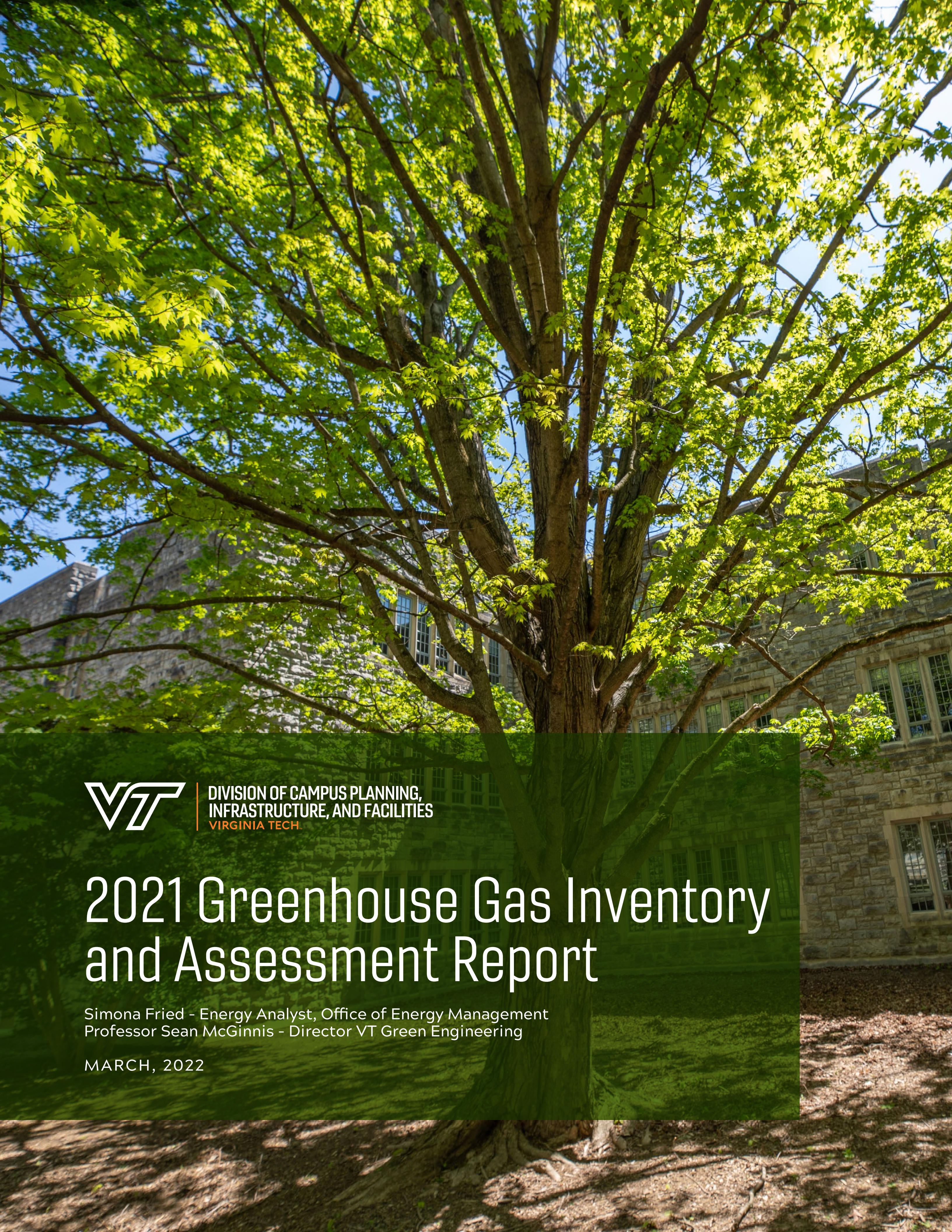

DIVISION OF CAMPUS PLANNING, INFRASTRUCTURE, AND FACILITIES
VIRGINIA TECH.

2021 Greenhouse Gas Inventory and Assessment Report

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MARCH, 2022

Introduction

Virginia Tech has completed a greenhouse gas (GHG) inventory and assessment since 2007 as part of its Climate Action Commitment. Greenhouse gases are chemicals that absorb heat in the upper atmosphere and lead to global warming. The dominant GHG is carbon dioxide (CO_2) which is emitted from the combustion of fossil fuels. Other important GHG emissions include methane (CH_4) and nitrous oxide (N_2O). These chemicals 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 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, campus plans and goals may not reduce emissions effectively and there can be a lack of accountability. Claims of carbon neutrality, in which all included emissions are reduced to zero or offset, require a greenhouse gas assessment to confirm compliance.

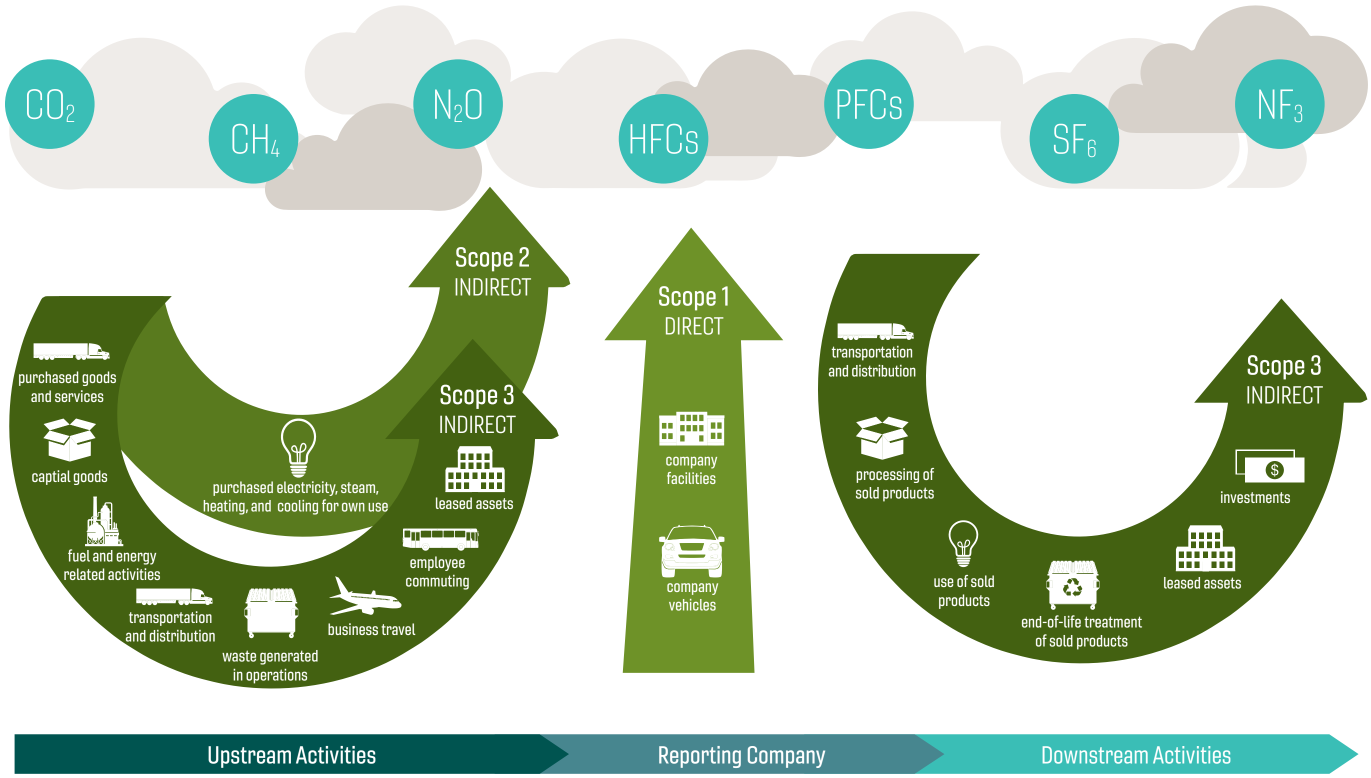
The 2021 GHG assessment supports Goal 1 of the Virginia Tech 2020 Climate Action Commitment which targets a carbon-neutral Virginia Tech campus by 2030. In this context, carbon neutral is defined as net-zero emissions of CO_2, CH_4, and N_2O across the Virginia Tech Blacksburg campus operations based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

This greenhouse gas assessment uses SIMAP, the Sustainability Indicator Management and Analysis Platform (SIMAP) developed by the University of New Hampshire. This is a common Greenhouse gas analysis platform used by universities around the U.S. Previous GHG assessments at Virgina Tech were compiled in an internal excel spreadsheet. 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

Greenhouse gas 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 greenhouse gas emissions include all other indirect emissions that occur because of campus operations, including both upstream and downstream emissions. For universities, Scope 3 emissions can include commuting, business travel, food, waste, water, etc. Scope 1 and 2 emissions are similar for the GHG assessments of most colleges and universities. Scope 3 emissions have fewer mandates and more data collection barriers. 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.

Figure 1. Scope Definitions for GHG Assessments[1]



The GHG emissions scope for this university assessment includes:

- Scope 1 (emissions from campus direct fuel use),
- Scope 2 (emissions related to purchased electricity), and
- Some Scope 3 emissions related to 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, like campus food which is reported in some college carbon footprints, these emissions sources are important to campus stakeholders based on the spring 2020 climate action surveys. Since anecdotal evidence from several universities suggests that these emissions can account for 5 – 10% of a campus carbon footprint and can be controlled by operational or student choices, the 2020 Climate Action Commitment Committee recommended analysis and tracking of dining hall food emissions as part of the annual GHG inventory.

A calendar-year time scope is used in this analysis with data compiled from Jan. 1 – Dec. 31, 2021, unless specifically mentioned otherwise. This requires data from the university from two academic and/or fiscal years (Jul. 1 - Jun. 30). The time-frame decision was made primarily due to the calendar year time-frame for emissions coefficients and Renewable Energy Credits (RECs). This GHG analysis was not completed for calendar year 2020 due to the changes as a result of COVID-19 protocols at Virginia Tech.

The geographic scope in this analysis includes all Virginia Tech owned lands and buildings on the main campus, buildings leased by university departments and the Virginia Tech Foundation in Blacksburg, and agricultural operations in the Blacksburg region. The gross square footage of the campus buildings in scope is approximately 10.2 million square feet. The leased-spaces, including the Virginia Tech Foundation and Corporate Research Center properties, is approximately 1.4 million square feet. The past university GHG assessments and the new scope boundaries used in the 2019-2021 assessments are listed in Figure 2. Figure 3 details specific scope elements for past university GHG assessments and the new scope elements for this 2021 assessment. The current scope was significantly expanded in 2019.

Figure 2. Comparison of Past (Pre-2019) and Current (2021) Geographical Scope Boundaries

Scope Boundaries	Pre-2019 Scope	Current 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
Virginia Tech Leased and Foundation Properties/Buildings	Out	In
International Campus Sites	Out	Out
Virginia Tech Carilion School of Medicine	Out	Out
Fralin Biomedical Research Institute at VTC	Out	Out
Virginia Tech Roanoke Center	Out	Out
Hotel Roanoke and Conference Center	Out	Out
Agricultural Research Extension Center (ARenewable energy credits)	Out	Out

Emissions from other Virginia Tech locations across the state and in other countries are not included in this assessment. However, methods and protocols developed for the Virgina Tech GHG assessment will be shared with other university operations in the Commonwealth to help these organizations do their own analysis.

Figure 3. Comparison of Past (Pre-2019) and Current (2021) Scope Elements

Scope Boundaries	Scope Type	Pre-2019 Scope	Current 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 Transmission and distribution Losses	3	Out	In
Upstream Natural Gas Drilling/Distribution	3	Out	In
Solid Waste	3	In	In
Wastewater	3	In	In
Water	3	In	In
Faculty/Staff/Student Commute	3	In	In
University Bus System	3	Out	In
Faculty/Staff Business Travel (Airlines)	3	Out	In
Dining Hall Food	3	Out	In
Compost/Landfill/Recycling	3	Out	In
Agricultural Operations (Fuel/Livestock)	3	Out	In
Agricultural Fertilizers	3	Out	In
Agriculture/Forest Land Use	3	Out	In

Methods

Inventory data corresponding to the emissions of greenhouse gas from the university 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.

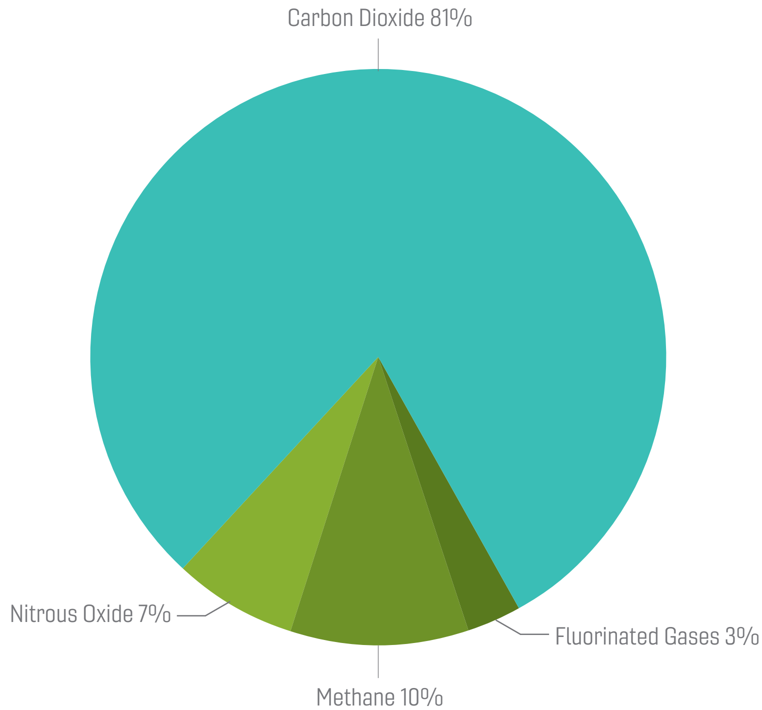
SIMAP®, the Sustainability Indicator Management and Analysis Platform, based at the University of New Hampshire, was the software providing the methodology for this GHG assessment. The carbon and nitrogen-accounting platform tracks, analyzes, and informs decisions that will improve campus-wide sustainability.

Global Warming Potentials and Carbon Emissions Factors

Greenhouse gases are a class of gaseous chemicals with properties which cause them to absorb radiation and heat up the atmosphere. As shown in Figure 4, approximately 98% 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 US 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 4. US GHG Emissions (CO_2e) by Chemical[2].

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

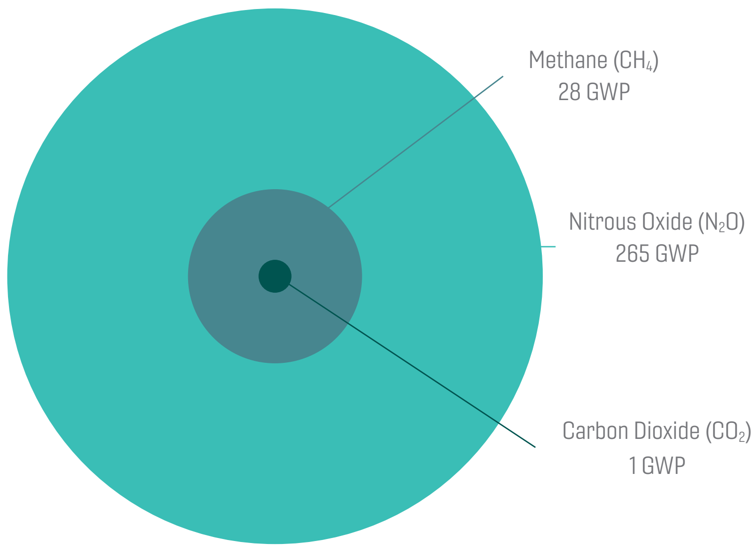


This assessment considers the main GHG, carbon dioxide, as well as methane and nitrous oxide which provide additional accuracy and highlight specific emission sources like natural gas leakage, waste and wastewater decomposition, and agricultural activities related to Virginia Tech's campus.

In a GHG analysis, the mass of each chemical emission is multiplied by its global warming potential 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 greenhouse gas and is given a global warming potential of 1.0. Chemicals with greenhouse gas 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 global warming potential depends upon the timeframe (number of years) under consideration due to the different lifetimes of the chemicals in the atmosphere. In this assessment, the global warming potential used are 100-year potentials from the International Panel for Climate Change (IPCC) Fifth Assessment Report (AR5),[3] shown in Figure 5.

Figure 5. IPCC AR5 Global Warming Potentials (GWP)



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 Global warming potentials in Figure 5.

Electricity, Steam, and Stationary Fuels for Main Campus

Electricity distributed by Virginia Tech Electric Service (VTES) to the university campus is purchased from Appalachian Power Company (APCO), a division of American Electric Power (AEP). Purchased electricity data (kWh) is compiled monthly by Virginia Tech 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 (WRI),[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 purchasing.

Virginia Tech operates a university Central Steam Plant to generate steam for campus heat, hot water, and electricity needs. The Central Steam Plant uses primary fuels to generate steam used for heating of buildings across campus and electricity. Currently, natural gas and 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 over 20 million kWh annually. This electricity generation increases the thermal efficiency of the plant and is sold to APCO and fed into the local electrical grid for distribution. The turbine was offline from July 2020 through February 2022 for repairs and refurbishment. Therefore, no electricity was generated from the turbine or included in the 2021 GHG report. In previous and future assessments, it has been assumed that all electricity produced on campus eventually serves campus buildings. Therefore, electricity generation from the Virginia Tech Central Steam Plant is subtracted from the total electricity usage values from APCO to avoid double-counting electricity emissions. The utility and steam plant electricity are shown in Figure 6. 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.

Figure 6. Main Campus and Steam Plant Electricity Usage and Generation

Electricity Category	CY2019 Electricity (kWh)	CY 2020 Electricity (kWh)	CY 2021 Electricity (kWh)
Education and General (E&G)	144,214,379	129,103,468	124,567,951
Auxiliary	63,108,898	55,027,068	59,113,525
Steam Plant Turbine Production	25,785,220	11,748,217	0
Total Purchased from Utility	181,537,999	172,382,319	183,681,475

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 APCO utility fuel mix. The purchased electricity has emissions based on the APCO fuel mix while the university Campus Steam Plant electric generation emissions are calculated separately based on emissions factors for the specific power plant primary fuel inputs (oil and natural gas in 2021).

Custom CO_2 emissions factors were used for APCO utility electricity for APCO and are shown in Figure 7. The carbon dioxide value was obtained from the Utility Specific Residual Mix Emissions Rate in the EEI Electric Company Carbon Emissions and Electricity Mix Reporting Database for Corporate Customers for 2021.[5] 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 2020 for the RFCW grid region (the 2021 data not available at the time of this report).[6] 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 emissions factors are higher than the SIMAP default emission factors which otherwise would be based on the RFCW eGRID data for Blacksburg, Virgina.

Figure 7. Custom Electricity Carbon Emissions Factors for APCO Utility Electricity

GHG	APCO 2021 Emission Factors (lb GHG/MWh)	APCO 2021 Emission Factors (kg GHG/kWh)
Carbon Dioxide (CO2)	1522	0.690
Methane (CH4)	0.086	0.000039
Nitrous Oxide (N2O)	0.012	0.0000054

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 Steam Plant based on the fuels used in this plant as detailed in Figure 8. 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 Facilities Engineering. 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, the natural gas provider). Note that the university Master Spreadsheet used a natural gas density of 1.027 MMBtu/MCF up until July 2020. Transmission and distribution electricity losses were also customized based on eGrid RFC West 2020 data and input into SIMAP. The latest available transmission and distribution loss information from 2020 indicated a 5.3% loss.[6]

Figure 8. Virginia Tech Stationary Fuel Usage

Stationary Fuels	2019	2020	2021
Coal (Steam Plant - short tons)	8,835	2,162	0
Oil (Steam Plant - gallons)	3,600	14,622	11,150
Natural Gas (Steam Plant - MMBTu)	1,005,236	1,009,530	1,015,091
Natural Gas (Buildings - MMBTu)	130,955	122,477	118,557

Renewable Energy Credits

No renewable energy credits were purchased in 2021 in contrast to the 90,220 APCO hydropower Renewable energy credits (55,405 MWh) purchased for the 2019 GHG Assessment. Each renewable energy credit offsets the emissions associated with 1 MWh of purchased electricity. If this equivalent amount of REC offsets were purchased in 2021, the net MTCDE would be reduced 13% (247,244 MTCDE).

Virgina Tech Blacksburg Leased Space

Virginia Tech leases space in buildings, both on the main 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. Brenda Williams and the Real Estate Office provided a majority of data, along with the support of Melissa Wren at the Virginia Tech Electric Service (VTES). This additional scope adds 48 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 (CRC).

Utility data availability varies due to collection processes. Estimates were used for the first half of 2021, as university spending is generally collected in fiscal year intervals. Additionally, estimates for leased space utility accounts provided by VTES were collected beginning in December 2021. Using a winter month and summer month, electric data was averaged for 12 months. The utility bills were adjusted given the assumption that Virginia Tech occupies, on average, 60% of the space in these buildings.

The natural gas usage was estimated from the utility bills by dividing the total costs ($) by the average natural gas ($/mcf) in 2021. The natural gas rate averaged $8.22/mcf in 2021. This average rate was determined using a series of Blacksburg ATMOS natural gas account bills. A small amount of error is introduced in this estimation since the total costs often include some costs which are not directly for the energy usage, but rather for account fees, taxes, etc. for several leased-space buildings. These estimated consumption values are shown in Figure 9.

Figure 9. Leased Space Energy Usage

Leased Space Utility	2019 Consumption	2020 Consumption	2021 Consumption	Units
Electricity	38,429,092	32,664,729	36,881,742	kWh
Natural Gas	23,744	23,744	7,409	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, university private jet aviation fuels, and university business airline passenger miles from trips booked through travel agencies. Out of 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 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 10 and based only on "revenue fuel," which is fuel directly used for the transit system. Electricity for new electric buses put into service in 2021 is included in this analysis and counted as a Scope 2 emissions, though Transportation is generally 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 diesel fuel 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 rather than campus activities.

Figure 10. BT Bus System Fuels

BT Buses	2021 Fuel
Diesel	262,517 gallons
Gasoline	23,581 gallons
Electricity	109,113* kWh

**Data is April – December 2021*

GHG emissions for commuters is difficult to estimate since neither miles driven or fuel usage data is available for all student, staff, and faculty commutes 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 office and a Spring 2020 campus survey. The details of this survey are available in the 2019 GHG Summary report. A summary of the number of permits sold by the university in fiscal year 2021 provided by Nick Quint is shown in Table 9 and was used as an estimate for the commuter analysis. A majority (97%) of the permit data (26,681/27,522 permits) was used in this analysis. The full permit data is shown in the Appendix 4.

The 2020 survey indicated many students without permits commute to campus. Some of these trips are drop-offs, pick-ups, or after-parking hours trips. Since the 2019 survey and data, the permit information in Figure 11 now includes daily permits. Non-permit holders were estimated by taking the total enrollment of undergrads (35,656 from the Fall 2021 Enrollment at **vt.edu/about/facts-about-virginia-tech**) minus the number of Commuter plus Resident Permits times the 30.4% of students from the 2020 survey who reported no-permit but still occasional commuting.

Figure 11. Virginia Tech Parking Permit Summary Data

Permit Type	# of Permits
FACULTY/STAFF (F/S)	8,532
Annual	4,515
Fall Semester	71
Spring Semester	435
Summer	50
Remote	290
Evening Annual	22
Evening Semester	13
Daily	2,068
Wage Monthly	929
Quarterly	139
GRADUATE STUDENTS	1,352
Annual	899
Fall Semester	142
Spring Semester	311

Permit Type	# of Permits
UNDERGRADUATE STUDENTS	16,797
Resident Annual	2,064
Resident Fall Semester	554
Resident Spring Semester	967
Resident Summer	33
Resident Daily	1,764
Resident Evening Annual	1,101
Resident Evening Semester	485
Commuter Annual	4,271
Commuter Fall Semester	1,373
Commuter Spring Semester	1,229
Commuter Summer	370
Commuter Remote	134
Commuter Daily	2,452

Total Permits: 26,681 | Percent Permits Used in Analysis: 96.9% | Non-Permit Commuters: 7,178

SIMAP estimates commute emissions from the number of commuters, the average number of commuter weeks/year, the number of one-way trips/week, and the number of vehicle miles per trip. The estimated commuter mileage is converted to fuel gallons and then emissions using average fuel economy data for vehicles in the US. The number of commuter permit-weeks for each type of permit were estimated based on the number of weeks for each type of permit and are shown in Figure 12. The number of one-way trips/week and vehicle miles/trip were taken from the 2020 commuter survey and are the same as in the 2019 GHG analysis. In future years, updated commuter survey data will be used. Daily permits commuter weeks/year were scaled based on one-way trips/week to account for two trips per day.

Figure 12. Virginia Tech Commuter Analysis Parameters

Permit Type	Average Commuter Weeks per Year
FACULTY/STAFF (F/S) One-Way Trips per Week: 12.0 | Vehicle Miles per Trip: 11.9	
Annual	46
Fall Semester	16
Spring Semester	16
Summer	10
Remote	46
Evening Annual	46
Evening Semester	16
Daily*	0.17
Wage Monthly	4
Quarterly	12
GRADUATE STUDENTS One-Way Trips per Week: 9.9 | Vehicle Miles per Trip: 4.5	
Annual	46
Fall Semester	16
Spring Semester	16
RESIDENT UNDERGRADUATE STUDENTS One-Way Trips per Week: 9.0 | Vehicle Miles per Trip: 1.5	
Annual	32
Fall Semester	16
Spring Semester	16
Summer	10
Daily*	0.22
Evening Annual	32
Evening Semester	16
COMMUTER UNDERGRADUATE STUDENTS One-Way Trips per Week: 17.0 | Vehicle Miles per Trip: 12.1	
Annual	32
Fall Semester	16
Spring Semester	16
Summer	10
Remote	32
Daily*	0.12
NON-PERMIT COMMUTERS One-Way Trips per Week: 8.5 | Vehicle Miles per Trip: 1.6	32

**Average commuter weeks per year for daily permits are calculated as two trips divided by the number of one-way trips/week for each category.*

The following analysis methodology was used to estimate commuting passenger-miles. For each commuter category, the number of purchased permit passes was multiplied by the number of estimated driving weeks for that category summed to get total permit weeks, and then finally divided by the total number of permits to get an average number of Commuting Weeks per Date Range for SIMAP. All commuting trips were entered into the SIMAP Commuting category at 100% since bus trips were previously accounted for in Transport Fuels as discussed above. Electricity for electric cars, scooters, and bikes are included only if the charging took place on campus; this under-estimate will need to be addressed in future report as electricity-based commuting increases. All trips were considered single passenger trips since we have no data to estimate car-pooling, but expect this assumption does not significantly affect the final estimates.

Undergraduate commuting data for Resident, Commuter, and No-Permit students was combined together under Student Commuting in SIMAP. Faculty, staff, and wage worker permits are combined into Faculty Commuting in SIMAP. Graduate student commuting is listed as Staff Commuting in SIMAP since SIMAP has only these three categories to choose from. Weighted values for weeks/permit, trips/week, and miles/trip were calculated by multiplying the commuting average survey values by the % of each type of commuter and summing them. These weighted values which were entered into SIMAP are detailed in Figure 13.

Figure 13. Virginia Tech Commuter Survey Analysis

SIMAP Category	Number of Commuters	Commuting Weeks per Date Range	Commuter One Way Trips per Week	Vehicle Miles per Trip	Vehicle Miles	Comments
Faculty Commuting	8,532	27.7	12.0	11.9	33,782,862	Faculty/Staff/Wage Workers
Student Commuting	23,975	23.0	12.1	1.8	11,595,132	Undergraduates (includes "no-permit" students)
Staff Commuting	1,352	35.9	9.9	4.5	2,165,219	Graduate Students
Total	33,859				47,543,214	—

Transport Fuels are listed in Figure 14 and were entered in SIMAP under Scope 1 Transport Fuels. This includes Fleet Service, Agricultural Operations, and Aviation Fuels. Data from Fleet Services fuel pumps were compiled from the Virgina 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 all so these Fleet Fuel values are under-estimates. Capturing the off-campus fuel purchases is recommended as a goal for the next assessment.

Data for Agricultural Operation fuels were not available this year so the data from 2019 was used as the best estimate. Aviation fuels (Jet Fuel A) were compiled by Melissa Ball at 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]

Figure 14. Virgina Tech Transport Fuels

Fleet, Agriculture Operations, and Aviation Fuels	Gallons
Fleet Services (Diesel)	29,385
Fleet Services (Gasoline)	190,630
Agriculture Operations (Diesel)	32,617
Agriculture Operations (Gasoline)	23,884
Aviation Fuel (Jet Fuel A)	32,468

Business Travel

The business travel scope in this 2021 assessment is limited to the incomplete fleet fuel data in the section above and airline travel. This airline data is also complex and 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 greenhouse gas assessment for this category is an under-estimate. Better methods for capturing all airline travel, independent of booking method, is recommended for the future.

Airline travel data for trips booked through the three primary university-approved travel agencies for fiscal year 2019 was obtained from Lynn Meadows, Senior Travel Consultant in the Virgina Tech Controller's Office. 2021 data was not available and the data used is based on the 2019 airline travel data. 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 Figure 15 from the EPA Center for Corporate Climate Leadership Greenhouse Gas Emission Factors Hub at the EPA Center for Corporate Climate Leadership website.[10]

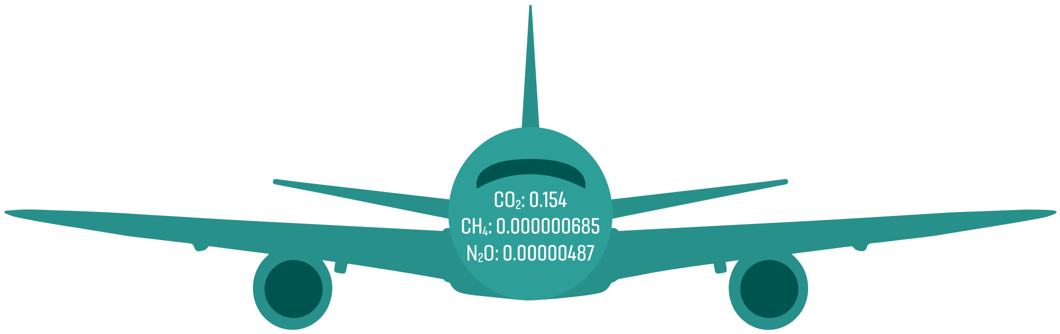
Figure 15. Airline EPA Air Travel Emission Factors

Flight Distance	CO_2 (kg/pass-miles)	CH_4 (g/pass-miles)	N_2O (g/pass-miles)
Long (> 2300 miles)	0.165	0.0006	0.0052
Medium (301-2299 miles)	0.133	0.0006	0.0042
Short (<300 miles)	0.215	0.007	0.0068

SIMAP uses a single set of CO_2, CH_4, and N_2O carbon emissions factors for airline flights. To use the better EPA data based on flight distance from Figure 15, 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 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 16 for SIMAP.

Figure 16. Weighted Airline Emissions Factors using EPA Data



It is also important to note that SIMAP applies a radiative forcing factor of 2.7 to all air travel emissions because the emissions are released at a higher altitude and cause a greater warming effect.[9] This additional factor is multiplied by the emissions factor in SIMAP.

Solid Waste & Wastewater

Municipal Solid Waste (MSW) and Wastewater data came from the Greenhouse gas Master spreadsheet. All of Virginia Tech's MSW goes to a landfill in Dublin, VA, and methane is recovered from the landfill to generate electricity according to Teresa Sweeney. In 2021, Virginia Tech produced 3,510 tons of MSW. This data was entered in SIMAP in the Waste & Wastewater category as Solid Waste: Landfilled Waste: CH_4 Recovery and Electric Generation which gives Greenhouse gas credit for the avoided emissions due to the electricity generation. 526 tons of compost from the university were sent to Royal Oaks Farm in Evington, VA in 2021. This was also added to the assessment report, but since it is processed by a third-party, Virginia Tech does not get to claim any carbon emissions credits.

In 2021, the university sent 556,819,167 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 (ATAD) and one Storage Nitrification De-nitrification Reactor (SNDR) which is mainly for the removal of ammonia. This wastewater was entered into SIMAP as Wastewater: Central Treatment System - Aerobic.

Figure 17. Virginia Tech Waste and Wastewater

Year	Total MSW Produced (Tons)	Total Wastewater Produced (Gallon)
2019	3,937	461,610,000
2020	2,597	512,620,000
2021	3,510	556,819,167

Agricultural Operations: Fertilizer, Livestock, and Land Use

Virgina Tech has agricultural operations on 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 18. These are the same values as for 2019 since data was not provided by the College of Agriculture for 2021.

Figure 18 - Virginia Tech Agricultural Animals

sheep: 750 head

swine: 465 head

horses: 110 head

beef cows: 800 head
dairy cows: 1,425 head

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 Figure 19. 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 % Nitrogen with a density of 8.5 lb/gallon assumed for the liquid manure. The % Nitrogen for the synthetic fertilizer and animal manure was assumed from common values in the literature. These are the same values as for 2019 since data was not provided by the College of Agriculture for 2021.

Virgina Tech compiles fertilizer data based on total nitrogen mass while SIMAP requires total fertilizer mass and % 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 were used for the nitrogen to N_2O conversion. Fertilizer and animals contribute approximately 4.2% of the total university Greenhouse gas emissions, more than the categories of commuting, buses, fleet fuels, or business air travel.

Figure 19. Virginia Tech Agriculture Operation Fertilizer Analysis

Fertilizer Type	TKN	Total N (lb)	% N in Fertilizer	Total Fertilizer Mass (lb)
Applied Liquid Dairy Manure	8.3 lb/kgal	24,402	0.098%	24,990,000
Applied Liquid Swine Manure	1.85 lb/kgal	2,017	0.022%	9,265,000
Applied Solid Dairy Manure	8.9 lb/ton	23,861	0.445%	5,362,000
Applied Solid Mixed Animal Manure	12.36 lb/ton	10,630	0.618%	1,720,000
Applied Synthetic Fertilizer	N/A	36,060	46%	78,391
Cattle Manure (land droppings)	N/A	230,299	3%	7,676,633
Sheep/Horse Manure (land droppings)	N/A	16,279	3%	542,633

Methane Leakage

Methane, commonly known as natural gas, is a potent greenhouse gas with a Global warming potential of 28. While natural gas is often discussed in news reports as a bridge fuel with lower Greenhouse gas emissions compared to coal, this is only considering the combustion of the fuels. If one includes the leakage of natural gas across its lifecycle, from mining to processing to distribution, the overall carbon footprint of this fuel is higher. Reports in the literature suggest that natural gas leakage in the range of 3% cause the life-cycle Greenhouse gas emissions of natural gas to be comparable to those for coal.[11] Including this Greenhouse gas emission source in the updated Virgina Tech Climate Action Plan was a major request by the university 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 Greenhouse gas Assessments, but it is similar to the electricity upstream transmission and distribution (T&D) losses which are typically reported in Scope 3.

The Greenhouse gas emission data from methane leakage due to upstream operations associated specifically with natural gas delivered to Virgina Tech is not available, but good scientific estimates of the average system leakage rates are available in the scientific literature. An analysis in 2018 estimated the overall methane leakage rate from the oil and natural gas supply chain at 2.3% (95% CI 2.0 - 2.7%).[12] Another recent synthesis article of methane emission data focused on the natural gas supply chain, production through distribution, and found that 1.7% (95% CI 1.3% to 2.2%) of the methane in natural gas is emitted between extraction and delivery.[13]

Based on the average value of these two scientific studies, we applied 2% leakage to all natural gas consumed by directly VT in the Central Power Plant, Buildings, and Leased Spaces. In addition, the primary natural gas used by the utility to generate electricity for the university campus, leased spaces, and Blacksburg Transit electric buses was included by considering the 22% natural gas fraction in the APCO 2021 fuel mix[14] and an assumed utility power plant efficiency of 35%. This leakage percent was multiplied by the total university natural gas consumption volume, converted to mass based on the gas density at 20°C and 1 atm,[15] and entered into SIMAP as a Scope 1 emission under the Category of Refrigerants and Chemicals. These emissions were manually adjusted to Scope 3 emissions in the results summary per Greenhouse gas protocols. The detailed methane leakage analysis is shown in Figure 20.

Figure 20. Virginia Tech Natural Gas Leakage Estimate

Upstream Methane Leakage Estimate	2019	2021
Natural Gas Leak Rate (from literature)	2.0%	2.0%
Virginia Tech Natural Gas (m3)	31,977,085	31,218,459
Virginia Tech Indirect Natural Gas (from utility electricity)(m3)	12,416,295	12,948,387
Natural Gas Leakage (m3)	887,868	883,337
Natural Gas Mass Density (kg/m3)	0.70	0.70
Total Methane <Mass Leakage (lb)	1,370,424	1,363,431

Results and Discussion

All Greenhouse gas 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 Figure 21, 22, and 23.

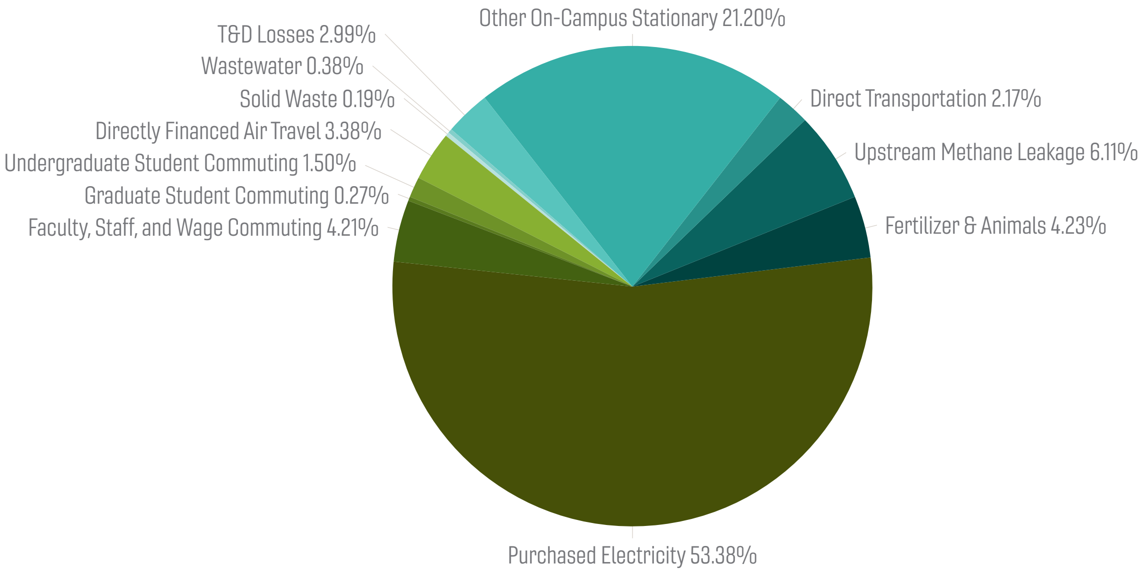
Figure 21. SIMAP Greenhouse Gas Emissions Results

Fiscal Year	Scope	Source	CO_2 (kg)	CO_2 (MTCDE)	CH4 (kg)	CH_4 (MTCDE)	N_2O (kg)	N_2O (MTCDE)	GHG (MTCDE)	GHG (% Annual Total)
2021	2	Purchased Electricity	152,263,908	152,264	8,606	241	1,200	318	152,823	53.51%
2019			123,257,006	123,257	11,898	33	2,172	5766	124,166	44.13%
2021	1	Other On-Campus Stationary	60,486,632	60,487	6,036	169	122	32	60,688	21.25%
2019			8,185,124	8.185	816	23	16	4	8,212	2.92%
2019	1	Co-gen Steam	52,150,931	52,151	5,328	149	281	74	52,375	18,62%
2019	1	Co-gen Electricity	17,214,575	17,215	1,759	49	93	25	17,288	6.15%
2021	1	Natural Gas Leakage	—	—	—	—	—	—	17,316	6.06%
2019									17,405	6.19%
2021	3	Faculty, Staff, and Wage Commuting	11,913,114	11,913	648	18	405	107	12,039	4.21%
2019			13,732,576	13,733	747	21	467	124	13,877	4.93%
2021	3	Transmission and distribution Losses	8,521,634	8,522	482	13	67	18	8,553	2.99
2019			13,705,818	13,706	1,323	37	242	64	13,807	4.91
2021	1	Fertilizer & Animals	—	—	374,773	10,494	6,096	1,616	12,109	4.24%
2019					374,773	10,494	6,096	1,616	12,109	4.30%
2021	3	Directly Financed Air Travel	9,155,116	9,155	15	0	107	28	9,184	3.26%
2019			9,155,116	9,155	15	0	107	28	9,184	3.22%
2021	1	Direct Transportation	6,175,774	6,176	120	3	91	24	6,203	2.17%
2019			7,599,056	7,599	128	4	108	29	7,631	2.71%
2021	3	Undergratuate Student Commuting	4,239,463	4,239	231	6	144	38	4,284	1.50%
2019			2,800,975	2,801	152	4	95	25	2,830	1.01%
2021	3	Wastewater	—	—	9,956	279	3,068	813	1,092	0.38%
2019					8,254	231	2,543	674	905	0.32%
2021	3	Graduate Student Commuting	764,346	764	42	1	26	7	772	0.27%
2019			917,651	918	50	1	31	8	927	0.33%
2021	3	Solid Waste	—	—	19,656	550	—	—	550	0.19%
2019					22,047	617			617	0.22%

Figure 22. SIMAP Greenhouse gas Emissions by Scope

Scope	2019 GHG(MTCDE)	2021 GHG (MTCDE)	2021 GHG (%)
1	115,021	96,317	33.7%
2	124,166	152,823	53.5%
3	61,273	36,474	12.8%
Total	281,335	285,614	100%

Figure 23. SIMAP VT 2-21 GHG Emissions by Category



The total estimated GHG for this assessment are 285,613 metric tons CO_2e. This is a 1.7% higher than the emissions of 2019. A large contributor to this increase is the fact that Renewable energy credits were purchased in 2019 to offset utility electricity emissions. The Scope 2 utility electricity is the largest emission category at 53%. The direct university emissions in Scope 1 account for 34%. The indirect emissions of Scope 3 are 13% of the total carbon footprint. The percentages are significantly different than in 2019 due to the Renewable energy credits.

Breaking this down by greenhouse gas chemical, 89% of these emissions are due to CO_2, 4% due to CH_4, and 1% due to N_2O. From a source perspective, 84% of the emissions results from operations and building energy from the utilities and the campus power plant. The emissions associated with losses due to electricity and natural gas distribution are 9% and not under the control of the university, though these values scale down linearly as energy use is reduced. Transportation fuels account for approximately 12% of emissions, with half of these attributed to faculty/staff/student individual car commuting, and can be reduced most easily and cost effectively through reduced use of vehicles, but also 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.

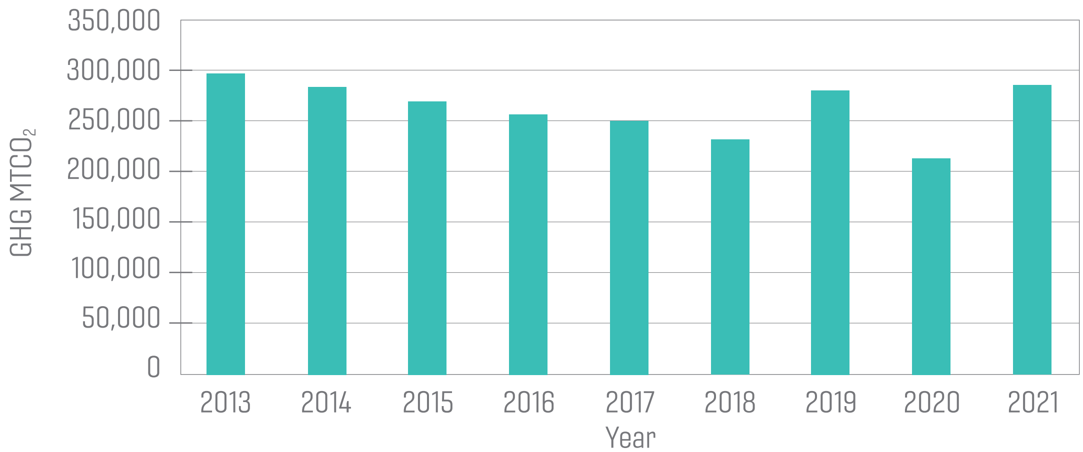
For context, Figure 24 and 25 previous assessment results, but the 2019 results shouldn't be directly compared given the significant changes in the method and the expanded scope of this assessment. The main changes are adding Leased Building Space, the Blacksburg Transit bus system, renewable energy credits, business air travel, electricity Transmission and distribution losses, and methane leakage. CH_4 and N_2O GHG emissions were also not considered in past assessments. Despite these scope additions, the total GHG emissions are only approximately 20% higher than estimated in 2018, mainly due to the hydropower Renewable energy credits which reduced the overall electricity emissions.

Figure 24. Past Virginia Tech Calendar Year GHG Assessment

Year	GHG (MT CO2)
2013	297,488
2014	284,489
2015	269,874
2016	257,244
2017	250,867
2018	232,260
2019	281,335
2020	213,720*
2021	285,613

**Estimated with limited analysis due to COVID-19 pandemic.*

Figure 25 - Annual GHG Assessment Total



Conclusions

The 2021 Virgina Tech GHG Emissions Assessment was completed during Fall semester 2022 using the expanded scope and methods recommended by the Greenhouse gas Subcommittee of the Spring 2020 Climate Action Committee (Climate Action Commitment). All recommended scope elements are included in this assessment except for Dining/Food Emissions and carbon sequestration by university agricultural/forestry lands and the campus tree canopy. This report is a critical piece of the Virgina Tech Climate Action Plan since it provides detailed data for future decisions and plans to reduce carbon emissions associated with the university.

Data collection was somewhat improved for the 2021 analysis, but Airline Travel and Agriculture Fuels and Animals, for example, were not provided for this year compared to 2019 due to staff logistics. Additional processes are recommended to ensure that this data is provided in a timely matter in future years given the university commitment to the Climate Action Commitment.

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 Virgina 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, Greenhouse gas Protocol FAQ, greenhouse gasprotocol.org/sites/default/files/standards_supporting/FAQ.pdf

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

[3]Greenhouse gas Protocol Website, Global Warming Potential Values, greenhouse gasprotocol.org/sites/default/files/greenhouse gasp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

[4]World Resources Institute (WRI), Greenhouse gas Protocol FAQ, Greenhouse gas Protocol Scope 2 Guidance, greenhouse gasprotocol.org/sites/default/files/greenhouse gasp/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 Greenhouse gas 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 Greenhouse gas 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-greenhouse gas-emission-factors-hub

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[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: VT GREENHOUSE GAS DATA SOURCE SUMMARY TABLE

Category	Data Source	Contact Information	Comments
Main Campus Electricity, Natural Gas, and Steam Plant Fuels	Virginia Tech Facilities and Master Spreadsheet	Simona Fried* | simonaf@vt.edu Energy Analyst, Office of Energy Management Todd Robertson | phrobert@vt.edu Associate Director Utilities, Power Plant Melissa Wrenn | wrenma@vt.edu Business Manager, Virginia Tech Electric Service (VTES) Mai George | Mai.George@atmosenergy.com Revenue Systems Analyst, Atmos Energy Corporation Wesley Gibson | gwesley7@vt.edu Engineering Controls Tech, VTES	—
Leased Space Electricity & Natural Gas	Utility Data VT Leased Space Spreadsheet	Brenda Williams | wbrenda@vt.edu Administrative Coordinator, Real Estate Management	—
Electricity Emission Factors	APCO Direct Contact	William Rogers | wgrogers@aep.com APCO Customer Account Manager Sean McGinnis | smcginn@vt.edu	Emissions factor values for 2019
Renewable Energy Credits (Renewable energy credits)	Virginia Tech Electrical Services	Rob Glenn* | robglenn@vt.edu VTES Director of Electrical Services	Source for 2019 Renewable energy credits
Fleet Fuels	VT Fleet Services	Anthony Dove | anthd69@vt.edu Fleet Operations Coordinator, 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	BT (Blacksburg Transit)	Tim Witten | twitten@blacksburg.gov Blacksburg Transit	—
Commuting Permits and Fuels	VT Transportation Office Commuter Survey	Nick Quint* | nquint@vt.edu Transportation Network Manager, Sustainable Transportation Sean McGinnis | smcginn@vt.edu	—
Airline Travel	Airline City Pair Spreadsheets	Lynn Meadows* | dlynnm06@vt.edu Senior Travel Consultant	Data only for travel agency airline bookings; data for 2019 only, not provided in 2021
Solid Waste	VT Master Spreadsheet	Teresa Sweeney | msrecycle247@vt.edu VT Engagement Specialist	—
Wastewater	VT Waste and Wastewater Master Spreadsheet	Suzanne Miller | sem0616@vt.edu 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	—

** identifies the primary contact for the data*

APPENDIX 2: SIMAP 2021 CUSTOM EMISSIONS FACTORS

Version	Fiscal Year(s)	Scope	Source	Emission Type	EF	Units
2021	2021 2020 2019	1	Direct Transportation Sources: University Fleet: Other (Liquid Fuels)	CH4	0.000000	kg / US gallon
2021	2019	3	Directly Financed Outsourced Travel: Air - Faculty/Staff	CH4	0.000001	kg / passenger mile
2021	2021 2020 2019	1	Direct Transportation Sources: University Fleet: Other (Liquid Fuels)	CO2	26.325000	kg / US gallon
2021	2019	3	Directly Financed Outsourced Travel: Air - Faculty/Staff	CO2	0.154000	kg / passenger mile
2021	2021 2020 2019	1	Direct Transportation Sources: University Fleet: Other (Liquid Fuels)	N2O	0.000300	kg / US gallon
2021	2019	3	Directly Financed Outsourced Travel: Air - Faculty/Staff	N2O	0.000005	kg / passenger mile

APPENDIX 3: VT PERMIT DATA

Permit Numbers	Permit Type	Count
22AA00001-22AA00050	AA 30 Year Employee	5
22AA00001-22AA00050	AA Year Hangtag	15
22FSA00001-22FSA06850	Faculty/Staff 30 Year Employee	451
22FSF06851-22FSF07000	Faculty/Staff 30 Year Employee	6
22FSA00001-22FSA06850	Faculty/Staff 30 Year Employee - Spring Semester	9
22FSA06851-FSA07000	Faculty/Staff 30 Year Employee - Spring Semester	3
22FSA00001-22FSA06850	Faculty/Staff Hangtag	3,919
22FSR00001-22FSR00150	Faculty/Staff Hangtag 21 Web - Fall Semester	53
22FSF00151-22FSF00200	Faculty/Staff Hangtag 21 - Fall Semester	14
22FSA00001-22FSA06850	Faculty/Staff Hangtag - Spring Semester	416
22FSA06851-22FSA07000	Faculty/Staff Hangtag - Summer	50
22FAM00001-22FAM00150	Faculty/Staff Bumper with Hangtag	29
22FAM00151-22FAM00200	Faculty/Staff Bumper with Hangtag	38
22FAM00001-22FAM00150	Faculty/Staff Motorcycle Bumper	1
22FAM00151-22FAM00200	Faculty/Staff Motorcycle Bumper	3
22WG00001-22WG01300	Faculty/Staff Wage - Quarterly	139
22WG00001-22WG01300	Faculty/Staff Wage - Monthly	929
22DFS00001-22DFS9999	Faculty/Staff - Daily (Excludes North End Garage)	2,068
22NE00001-22NE01000	New Employee Permit	456
22NEMP00001-22NEMP10000	New Employee Permit	261
22SRA00001-22SRA00500	Student Remote 22	104
22SRA00501-22SRA00600	Student Remote	30
22SD00001-22SD05000	Student - Daily	106
22PCA00001-22PCA01400	Perry St. Commuter - Year	912
22PCA01401-22PCA01500	Perry St. Commuter 21 - Year	15
22DCGP0001-22DCGP9999	Perry St. Commuter/Graduate - Daily	1,033
22PGA00001-22PGA00550	Perry St. Area Graduate	214
22PGA00551-22PGA00650	Perry St. Area Graduate 21	9
22PSD00001-22PSD02000	Perry St. - Daily	19
22RAA00001-22RAA00100	Resident Advisor Hangtag	56
22RAA00101-22RAA00150	Resident Advisor Hangtag	13
22RAA00101-22RAA00150	Resident Advisor Hangtag - Spring Semester	9
22RAA00001-22RAA00100	Resident Advisor Hangtag - Spring Semester	9
22RSA00001-RSA02200	Resident Hangtag Web	1,300
22RSA02201-22RSA02750	Resident Hangtag	397
22RSF00001-RSF00550	Resident Hangtag Web - Fall Semester	412
22RSA00001-22RSA02200	Resident Hangtag Web - Spring Semester	460
22RSA02201-22RSA02750	Resident Hangtag - Spring Semester	361
22RAM00001-22RAM00050	Resident Motorcycle Bumper - Year	5
22RFM00001-22RFM00050	Resident Motorcycle Bumper 21 - Fall Semester	1
22DRS00001-22DRS9999	Resident Student - Daily	1,639
TOTAL		27,522

Permit Numbers	Permit Type	Count
22CSA00001-22CSA03100	Commuter Hangtag Web - Year	2,935
22CSA003501-22CSA06000	Commuter Hangtag	327
22CAM00001-22CAM00150	Commuter Bumper with Hangtag	12
22CAM00001-22CAM00050	Commuter Motorcycle Bumper	28
22CSF01001-22CSF01200	Commuter Hangtag - Fall Semester	181
22CSF01201-22CSF01600	Commuter Hangtag - Fall Semester	273
22CSA03101-22CSA03500	Commuter Hangtag - Summer	370
22CFM00001-22CFM00050	Commuter Bumper with Hangtag - Fall Semester	2
22CFM00001-22CFM00050	Commuter Motorcyle Bumper - Fall Semester	5
22CSF00001-22CSF01000	Commuter Hangtag Web - Fall Semester	907
22DCG00001-22DCG9999	Commuter/Graduate - Daily	1,419
22GSA00001-GSA01700	Graduate Hangtag Web	652
22GSA01701-22GSA02000	Graduate Hangtag 21	24
22GAM00001-22GAM00100	Graduate Bumper with Hangtag 21	10
22GAM00001-22GAM00100	Graduate Motorcycle Bumper 21	3
22GSF00001-GSF00250	Graduate Hangtag Web - Fall Semester	136
22GSF00251-GSF00300	Graduate Hangtag 21 - Fall Semester	6
22GSA00001-GSA01700	Graduate Hangtag Web - Spring Semester	277
22GSA01701-22GSA02000	Graduate Hangtag - Spring Semester	34
22OAK00001-22OAK00450	Oak Lane	294
22OAK00451-22OAK00500	Oak Lane Web	4
22OAF00001-22OAF00400	Oak Lane Web - Fall Semester	141
22OAF00401-22OAF00450	Oak Lane - Fall Semester	1
22OAK00001-22OAK00450	Oak Lane - Spring Semester	123
22OAK00451-22OAK00500	Oak Lane Web - Spring Semester	5
22CPA00001-22CPA00500	Student Carpool Hangtag	82
22CPF00001-22CPF00150	Student Carpool Hangtag - Fall Semester	12
22FCA00001-22FCA00250	Faculty/Staff Carpool Hagtag - Year	139
22FCF00001-22FCF00050	Faculty/Staff Carpool Hangtag - Fall Semester	4
22FCA00001-FCA00250	Faculty/Staff Carpool Hangtag - Spring Semester	7
22EO00001-22EO00400	Student Evenings Only	268
22EO00401-22EO01550	Student Evenings Only (Not Valid in 24hr F/S Lots)	833
22EO00001-22EO00400	Faculty/Staff Evenings Only	10
22EO00401-22EO01550	Faculty/Staff Evenings Only (Not Valid in 24hr F/S Lots)	12
22EO00001-22EO00350	Faculty/Staff Evenings Only - Semester	10
22EO00351-22EO00700	Student Evening Only - Semester	244
22EO00001-22EO00350	Student Evening Only - Semester	241
22EO00351-22EO00700	Faculty/Staff Evening Only - Semester	3
22FSR000001-22FRS00350	Faculty/Staff Remote Web	272
22FSR00351-22FSR00400	Faculty/Staff Remote	18
TOTAL		27,522

APPENDIX 4: METHANE LEAKAGE ANALYSIS

Inputs		Comments
Upstream Methane Leakage Estimate	Value	
CY21 Natural Gas Consumption		
Power Plant	980,764 MCF	Data from VT Facilities group Master Spreadsheet converted from MMBTu using 1.035 MMBTu/MCF
Buildings	114,548 MCF	
Leased Space	7,158 MCF	Updated from Leased Space natural gas data
Total Campus	1,102,471 MCF	
	31,218,459 M^3	35.3147 ft3 = 1 m3
CY21 Purchased Electricity Consumption		
APCO Electricity (Campus)	183,681,476 kWh	Data from VT Facilities group Master Spreadsheet
APCO Electricity (Leased Space)	36,881,742 kWh	Data from Leased Space Spreadsheet (S. Johnson)
Electric Bus Electricity (Blacksburg Transit)	109,113	Electric buses implemented in April 2021
Total APCO Electricity	220,672,331 kWh	
PP Efficiency	35%	Power Plant efficiency assumption
NG Primary Fuel (Input)	630,492,374 kWh	
NG Primary Fuel Percentage	22%	APCO NG% fuel mix from APCO 2021 Fuel Mix in EEI Database[1]
NG Primary Electricity Share	138,708,322 kWh	
NG Primary Energy Input	473,273 MMBTtu	Energy conversion from kWh to MMBTu
NG Energy Density	1.035 MMBTu/MCF	Energy density from Atmos
NG Volume	457,268 MCF	
Indirect Natural Gas for Electricity	12,948,387 m^3	35.3147ft^3 = 1 m^3
Total NG	44,166,846 m^3	
Natural Gas Leak Rate	2.0%	Average leak rate for 2 scientific articles[2,3]
VT Direct Natural Gas	31,218,459 m^3	
VT Indirect Natural Gas from Electricity	12,948,387 m^3	
Methane Leakage	883,337m^3	
Natural Gas Mass Density	0.700 kg/m^3	unitrove.com/engineering/tools/gag/natural-gas-density @ 20C. 1atm
Total Natural Gas Mass Leakage	618,336 kg	
Natural Gas Mass Leakage	1,363,431 lb	