2019 Greenhouse Gas Inventory and Assessment Report

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Introduction

Virginia Tech has completed a Greenhouse Gas (GHG) Inventory and Assessment Report since 2007 as part of its Climate Action Commitment (CAC). GHGs 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 CAC 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 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 current CAC, approved in 2013, states in point 13 that:

> *"Virginia Tech will monitor energy use and GHG emissions as well as changing internal and external conditions, prepare an annual 'report card' showing progress towards targets, and periodically re-evaluate targets, making adjustments to targets as appropriate based on changing internal and external conditions and evolving technologies."*

The 2019 GHG assessment also supports the spring 2020 Climate Action Committee (CAC) recommendation of a carbon-neutral VT campus by 2030. In this context, carbon neutral is defined as net-zero emissions of CO_2, CH_4, and N_2O by VT operations at the Blacksburg campus based on geographic and GHG scope of 2020 CAC. The CAC resolution was approved by the University Council in November 2020 and will be voted on by the Board of Visitors in Spring 2021.

This GHG assessment uses SIMAP, the Sustainability Indicator Management and Analysis Platform (SIMAP) developed by the University of New Hampshire. This is the most common GHG analysis platform used by universities around the US. Previous GHG assessments at VT used an internal excel spreadsheet compiled and analyzed by the Facilities department. Moving to a formal GHG platform will standardize this process and allow for more accurate and consistent analyses from year-to-year.

GHG SCOPE AND BOUNDARIES

GHG protocols differentiate between Scope 1, 2, and 3 emissions as summarized in 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 not included in the other scopes that occur in the supply chain, including both upstream and downstream emissions. For universities, this includes items like 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 are handled differently by institutions which can make it difficult, and often inappropriate, for direct comparisons among schools.
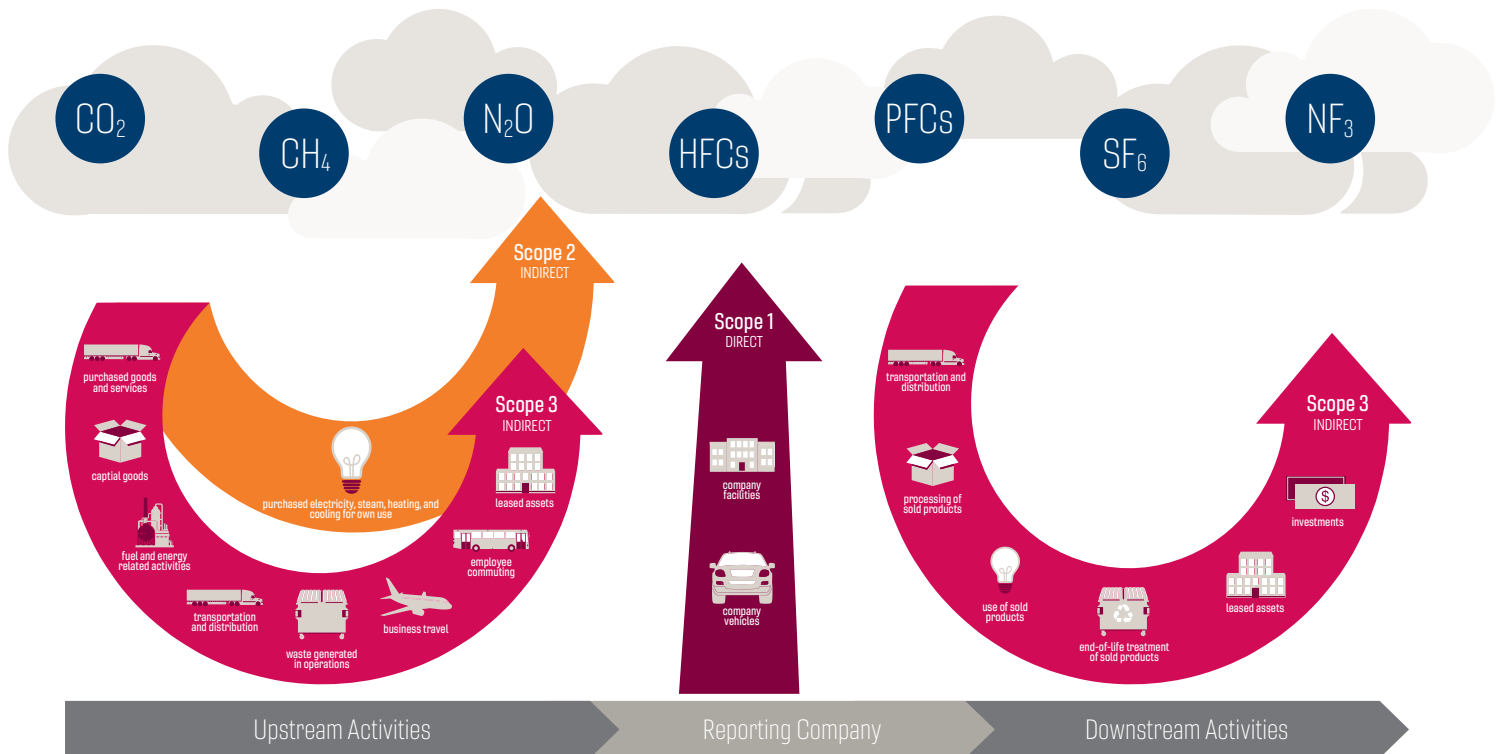

Figure 1. Scope definitions for GHG assessments[1]

The GHG emissions scope for this VT 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
- · Commercial business travel miles
- · Utility transmission and distribution (T&D) losses
- · Upstream natural gas (methane) direct leakage

Other commonly reported Scope 3 emissions include emissions associated with campus food and sequestration of carbon by trees and land. Upstream Scope 3 emissions for dining hall food will not be in scope for this assessment due to the scale of the data and analysis required for accurate results. Sequestration of carbon in Virgina Tech forestry and agricultural lands was also not included in this assessment due to lack of data and analysis time. Both of these 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 occasionally, these emissions sources are very important

to some stakeholders on campus as learned in the spring 2020 climate action surveys. Since these emissions can account for 5-10% of a campus carbon footprint and can be controlled by operational or student choices, they have been recommended by the 2020 CAC Committee to be tracked and analyzed as part of annual GHG inventory.

A calendar-year time scope is used in this analysis with data compiled from January 1-December 31, 2019, unless specifically mentioned otherwise. In some cases, this requires data from the university from two academic and fiscal years (July 1-June 30). The biggest advantage of this choice is that emissions coefficients and Renewable Energy Credits (RECs) are much easier to handle since they are based on a calendar year.

The geographic scope includes all Virginia Tech owned lands and buildings on the main campus, all buildings leased by university departments in Blacksburg, and agricultural operations in the Blacksburg region. The gross square footage of the main campus buildings in scope is approximately 10.2 million square feet while the leased-space is approximately 1.4 million square feet. Table 1 details the scope boundaries for past assessments and the new scope for this 2019 assessment. Table 2 details specific scope elements for past GHG assessments and the new scope elements which significantly expand this 2019 assessment.

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 GHG Assessment will be shared by 2022 to other university operations in the Commonwealth and they will be encouraged to establish their own GHG reduction targets, goals, and pathways.

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.

Scope Boundaries	Past Scope	2019 Scope
Main Campus	In	In
Athletic Facilities	In	In
University Airport	In	In
Agricultural Facilities	In	In
Foundry	In	In
Architectural Research Building	In	In
International Campus Sites	Out	Out
Virginia Tech Carilion School of Medicine	Out	Out
Leased and Foundation Properties/Buildings	Out	In
Fralin Biomedical Research Institute at VTC	Out	Out
Virginia Tech Roanoke Center	Out	Out
Virginia Tech Foundation	Out	Out
Hotel Roanoke and Conference Center	Out	Out
Agricultural Research Extension Centers (ARECS)	Out	Out

Table 1. Comparison of previous and new (2019) geographical scope boundaries

Scope Boundaries	Scope Type	Past Scope	2019 Scope
Coal (steam plant)	1	In	In
Oil (steam plant)	1	In	In
Natural Gas (steam plant)	1	In	In
Natural Gas (buildings)	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
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	Out*
Compost/Landfill/Recycling	3	Out	In
Agriculture Operations (fuel and livestock)	3	Out	In
Agriculture/forest land use	3	Out	In

*Planned for 2020 assessment

Table 2. Comparison of previous and new (2019) scope elements

An independent study team of undergraduate students from the Green Engineering Program supported data analysis and software entry. Additional staff were used to obtain, verify, and check the data and analysis. The Virginia Tech Office of Sustainability and Facilities Engineering Operations were particularly helpful.

The methodology for this GHG assessment was SIMAP®, the Sustainability Indicator Management and Analysis Platform based at the University of New Hampshire. SIMAP® is a carbon and nitrogen-accounting platform that can track, analyze, and 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 97% of the carbon dioxide equivalent (CO_2e) emissions by mass 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. GHG emissions analyses are also 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.

All GHG Assessments prior to 2019 have only accounted for CO_2 emissions and neglected the other GHGs. For this 2019 assessment using SIMAP, methane and nitrous oxide will also be included for additional accuracy and to highlight some specific emission sources like natural gas leakage, waste and wastewater decomposition, and agricultural activities related to campus.

In GHG analysis, the mass of each chemical emission is multiplied by its **global warming potential (GWP)** which quantifies 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 1 will warm the atmosphere more than an equivalent mass of CO_2 while chemicals with GHG values lower than 1 will warm the atmosphere less.

Figure 2. US GHG Emissions CO_2e by Chemical[2] in 2018. Rounding of the results leads to a total greater than 100%

GHG	Global Warming Potential (lb CO2e/lb)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous Oxide (N_2O)	265

Table 3. IPCC AR5 Global Warming Potentials

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

SIMAP uses the campus inventory data including electricity (kWh), fuel (gals), waste mass (kg), and the other data detailed in the sections that follow since CO_2 emissions are difficult to measure directly. This inventory data was converted to GHG emissions (CO_2, CH_4, N_2O) using the default 2019 SIMAP emissions factors shown in Appendix 2 unless otherwise stated. SIMAP also translates all of the emissions into carbon dioxide equivalents (CO_2e) based on the different GWPs in Table 3.
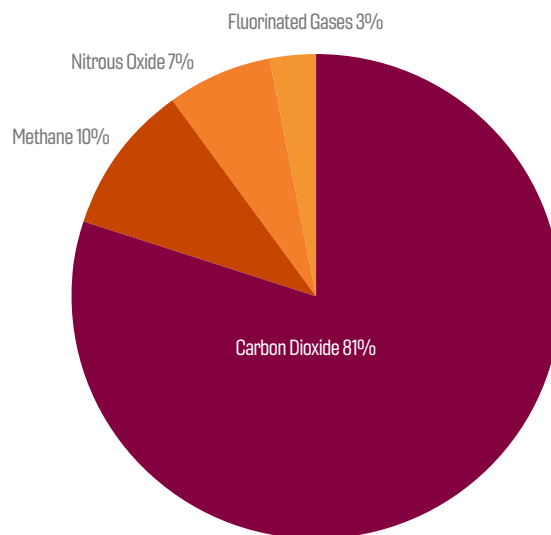
ELECTRICITY, STEAM, AND STATIONARY FUELS FOR MAIN CAMPUS

Electricity for the Blacksburg campus is purchased from Appalachian Power Company (APCO), a division of American Electric Power (AEP). Purchased electricity data (kWh) is compiled monthly by the Virginia Tech Facilities Department 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 campus GHG assessments.

Main Campus and Steam Plant Electricity Usage and Generation in CY19

144,214,379 kWh
For education and general usage (E&G)

63,108,898 kWh
for Auxiliary usage

25,785,220 kWh
for steam plant turbine production generation

181,537,999 kWh
total purchased from utility

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 purchased renewable energy credits (RECs).

Virginia Tech is unique in that it operates a university Central Steam Plant and the Virginia Tech Electric Service (VTES) to generate electricity and steam for campus operations. The Central Steam Plant uses primary fuels to generate electricity and steam used for heating of buildings across campus. Coal, fuel oil, and natural gas are used in the boilers to generate this steam. Before being used for heating, this steam is 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 grid for distribution. For this assessment, as was the case with previous assessments, it is assumed that all electricity produced on campus eventually serves campus buildings. Therefore, electricity generation from the Central Steam Plant was considered a negative value and subtracted from the total electricity use from APCO to avoid double-counting emissions. The utility and steam plant electricity data is detailed in the box above. The total purchased utility electricity was entered into SIMAP as a Scope 2 Emission under the category of Utility Consumption. The 100-kWh solar array on the Perry St. Garage is net-metered so the energy generation (approximately 133,472 kWh) is accounted for in the electric consumption data and is therefore not entered separately.

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

Custom emissions factors were used for utility electricity from APCO and are shown Table 4. These values from APCO are the 2019 Utility Averages which are not adjusted for REC activity. The CO_2, CH_4, and N_2O lb CO_2e/MWh values in the second table column were divided by the AR5 GWP values for each chemical from Table 3 and then converted to the mass of each GHG per MWH which was entered into SIMAP under *Utility Emission Factors* and the source *Electricity, Steam Chilled Water: Electricity*. Note that these emissions factors are higher than the SIMAP default emission factors which otherwise would be based on the RFCW eGRID data for Blacksburg, VA.

Fuels burned in the Virginia Tech Central Steam plant (coal, 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 VT Steam 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 steam efficiency as calculated by Virginia Tech Facilities using the EPA Combined Heat and Power website.[5]

GHG	APCO 2019 Emission Factors (lb CO2e/MWh)	APCO 2019 Emission Factors (lb GHG/MWh)	APCO 2019 Emission Factors (kg GHG/kWh)
Carbon Dioxide (CO₂)	1651.2	1651.2	0.749
Methane (CH₄)	4.462	0.159	0.0000723
Nitrous Oxide (N₂O)	7.697	0.029	0.0000132

Table 4. Custom Electricity Carbon Emissions Factors for APCO Utility Electricity

Stationary Fuels	Quantity	Energy (MMBtu)
Coal (VT Steam Plant)	8,834.5 short tons	227,930
Oil (VT Steam Plant)	3,600 gals	497
Natural Gas (VT Steam Plant)	978,808 MCF	1,013,066
Natural Gas (Buildings)	127,398 MCF	131,857

Table 5. Virginia Tech Stationary Fuel Usage

Fuel amounts were converted to energy (MMBtu) for SIMAP using the following energy densities: 25.8 MMBtu/ton for coal (average values from coal heat input), 138,000 Btu/gal for oil (low sulfur), and 1.035 MMBtu/MCF for natural gas (energy density from Atmos, the natural gas provider).

Transmission and distribution (T&D) losses were also customized based on APCO data and input into SIMAP. The latest available T&D loss information from 2016 indicated a 7.68% loss based on Net System Output Analysis.[6]

RENEWABLE ENERGY CREDITS (RECS)

90,222 Vintage 2019 Hydropower Renewable Energy Certificates (RECs) sourced from APCO's Claytor Lake Facility, located approximately 20 miles from Virginia Tech on the New River, were purchased and retired on behalf of VTES on March 26, 2020. These RECs represent 20% of the total electric energy purchased by VTES in CY2019.

VTES serves electric customers on both campus and in the Town of Blacksburg. The VTES total electrical energy includes the electricity both purchased from APCO and generated by the VT Central Steam Plant. Electrical energy attributed to the Blacksburg campus includes the metered campus electricity consumption and the power plant electricity generation. This portion of campus electricity relative to the total VTES was 61.41% in 2019, therefore only 55,405 RECs were claimed by the University for this GHG assessment.

These credits were entered in SIMAP as Voluntary Unbundled RECs under Scope 2 *Renewable Energy*. SIMAP subtracts this amount of electricity (55,405 MWh) from the VT Scope 2 electricity amount before calculating the GHG emissions.

Math Emporium

Kent Square

University Gateway Center

North End Center

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 added to the scope of this GHG assessment. Therefore, the associated emissions were added to the scope of this GHG assessment. Leased-space data including electricity and natural gas usage is summarized in the box to the left. This additional scope includes 55 leased-space buildings with approximately 1.4 million square feet of space including some 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).

41,440,809 kWh of Electricity and

22,941 MCF of Natural Gas are used in leased spaces
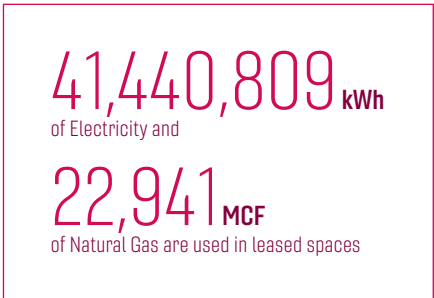
Utility data in this spreadsheet was available only as utility bill costs rather than the more accurate energy usage values required by SIMAP. The energy usage was estimated from the utility bills by dividing the total costs ($) by the average Virginia Tech energy costs for electricity ($/kWh) and natural gas ($/mcf) in 2019. 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, the utility bills were only available for the entire building, though Virginia Tech only occupies a fraction of the total building space. In these cases, the utility bills were linearly adjusted based on the Virginia Tech occupancy percentage (%). The electricity rate used for these utility bill conversions was $0.0914/kWh from Rob Glenn of VTES and the natural gas rate was $5.886/mcf from an ATMOS natural gas bill in 2019.

TRANSPORTATION

Transportation emissions in the scope of this assessment include the BT bus system fuels, commuting miles for faculty/staff/students, Fleet Services fuels, agricultural operation fuels, Virginia Tech private jet aviation fuels, and Virgina Tech 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 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 BT Bus system were included based on direct fuel use provided from Erik Olsen at Blacksburg Transit. SIMAP calculates commuter emissions based on passenger-miles, but the direct fuel gallons are both easier to obtain and more accurate for bus emission estimates. These direct fuel values were entered in SIMAP as Transport Fuels but re-classified as Scope 3 emissions per GHG protocols. There is currently no easy or accurate way to separate student, faculty, staff, and town resident bus trips so all bus fuel was attributed to Virginia Tech in this assessment. This is likely a slight overestimate of emissions

since some small fraction of bus trips are made which are related to town rather than campus activities.

GHG emissions for commuters are more 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 a fraction of all commuters, the Virginia Tech estimates were based on both permit data from the Transportation Services office and a Spring 2020 campus survey. The number of permits sold in academic year 2018-19 is shown in Table 6 and was used as an estimate of commuters. The number of permit-weeks for each type of permit was also estimated based on the number of weeks in a semester and year considering holiday breaks. The 2019 calendar-year data was not fully available at time of this assessment so the previous year was considered to be a good and reasonably accurate option. In the future, the academic-year permit data will be adjusted to calendar-year data for consistency.

297,712 gal
of diesel were used in Blacksburg Transit Buses in 2019

The commuter survey questions are detailed in Appendix 4 with the following critical questions for this assessment: (1) the type of permit, (2) the number of days driving per week, (3) the number of roundtrips per day, and (4) the average commuting distance. The survey data was analyzed to match the SIMAP required entries of Trips/Week and Miles/Trip. SIMAP default emissions factors per passenger-mile were used for all commuting estimates. There are a number of minor issues with the commuter survey, but overall the responses provided good average values to be used for the different commuter permit groups. The survey response numbers detailed on the next page. The undergraduate student data offers an excellent sample size since the survey was encouraged in Dr. Greg Tew's large Design Appreciation class (ITDS 1114) which had approximately 2,700 students and an estimated distribution of 35% freshmen, 25% sophomores, 20% juniors, and 20% seniors. The faculty and staff sample size is also reasonable, but the sample size for graduate students and wage workers was lower than desirable.

Permit Type	Faculty/Staff	Wage Worker	Graduate Student	Commuter (off-campus)	Resident (on-campus)
Number of permits with assumed weeks of use per permit in parenthesis					
Yearly	5,482 (47)	N/A	954 (47)	2,368 (32)	1,312 (32)
Fall Semester	125 (16)	N/A	604 (16)	1,626 (16)	1,288 (16)
Spring Semester	458 (16)	N/A	174 (16)	746 (16)	546 (16)
Summer	149 (10)	N/A	103 (10)	332 (10)	73 (10)
3-Month	N/A	188 (12)	N/A	N/A	N/A
Monthly	N/A	495 (4)	N/A	N/A	N/A
Total	**6,214**	**683**	**1,835**	**5,072**	**3,219**

Table 6. Virginia Tech Parking Permit Data

Commuter Survey Responses by Category

Students:

966 Undergraduate **40** Graduate

Employees:

267 Staff **210** Faculty **4** Wage Workers

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 permit from Table 6, summed to get total permit weeks, and finally divided by the total number of permits to get an average number of Commuting Weeks per Date Range for SIMAP. The survey data was analyzed to get average values for each permit/commuter type for one-way-trips per commuter per week and vehicle-miles-per-trip. This data is shown in Table 7. Only automobile trips were entered into the SIMAP Commuting category at 100% since bus trips were accounted for in Transport Fuels and Virginia Tech has no other significant powered commuting options that lead to GHGs. Electric scooters were new to campus in this reporting year, but no electricity data or commuting data was available yet. Scooter electricity will be analyzed in the future as part of this assessment. Data was obtained in the survey for the percentage of commuting trips by walking, bike, bus, car, etc., but this data is not reported here. 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.

There were some differences from the survey data between trips and miles per trip for faculty, staff, and wage workers, but the distribution of these permits was not known so all of these groups were averaged together for entry into SIMAP under Faculty Commuting. Graduate students took fewer trips and commuted shorter distances than faculty and staff. Graduate student and undergraduate commuting data was entered separately in SIMAP. The undergraduate commuter data was both more robust and more difficult to interpret. Commuter permit holders (students who live off campus) drove nearly twice as many times and more miles to campus each week compared to Resident permit holders (students who live on campus) who must park in remote lots. Responses from resident permit holders who indicated more than a 10-mile roundtrip were not considered in the analysis as these responses likely included weekend trips home and back which were out of scope for this analysis.

Surprisingly, many undergraduate drivers indicated in the survey that they did not purchase a permit. 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 using the following equations:

No-Permit Students: Total undergrad enrollment-Undergrad Permits (Commuter+Resident)

$$29{,}250 - 8{,}291 = 20{,}959$$

No-Permit Commuter: No-Permit Students x Fraction of No-Permit Drivers from the Survey

$$20{,}959 \times (486 \div 1597) = 20{,}959 \times 30.4\% = 6{,}378$$

Undergraduate commuting data for resident, commuter, and no-permit students was combined under **Student Commuting** since these different groups could not be entered separately in SIMAP. Weighted values for weeks/permit, trips/week, and miles/trip were calculated by multiplying the commuting average survey values by the percent of each type of commuter and summing them. These weighted values are shown in the last row of Table 7, and when compared to the value calculated by using the total number of student commuters, the passenger-miles were within 4% of the total undergraduate value calculated separately.

Commuting Category	Number of Permits	Average Commuter Weeks/Year	One Way Trips per Week	Vehicle Miles per Trip	Survey Responses Used	Estimated Miles
Faculty/Staff/Wage Workers	6,897	39.5	12.0	11.9	481	38,903,218
Graduate Students	1,835	31.8	9.9	4.5	40	2,575,101
Undergraduate: Commuters	5,072	23.1	17.0	2.1	374	7,938,145
Residents	3,219	22.4	9.0	1.5	73	
No Permit Commuters	6,378	32	8.5	1.6	486	
Weighted Undergraduates (for SIMAP)	14,669	26.8	11.6	1.74	933	7,921,613

Table 7. Virginia Tech Commuter Survey Analysis

Transport Fuels are listed in Table 8 and were entered in SIMAP under Scope 1 Transport Fuels. This includes Fleet Service, Agricultural Operations and Aviation Fuels. Data from Fleet Services represents the fuel purchased from Fleet Services Fuel Pumps for all Virginia Tech 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 was not available and there is no current mechanism to capture it all so these Fleet Fuel values are under-estimates. Fuels from Agricultural operations were also compiled by Jody Booze-Daniels. Aviation fuels (Jet Fuel A) were compiled by Melissa Ball at Air Transportation Services and

Fuels	Gals
Fleet Services - Diesel	33,363
Fleet Services - Gasoline	230,001
Agriculture Operations - Diesel	32,617
Agriculture Operations - Gasoline	23,884
Aviation Fuel - Jet Fuel A	66,405

Table 8. Virginia Tech Transportation Fuels

accounted for fuel purchased locally at the Montgomery County Airport and at destination airports. The planes are co-owned by Virginia Tech and a non-university group in Roanoke. The split of Virginia Tech-related and non-Virginia Tech flights was estimated at 50 percent each for 2019. The data was not compiled in a way that allows easy separation of these flights, but the data will be collected differently for a more accurate analysis in the future. Custom emissions factors for Jet Fuel A were entered into SIMAP from an EPA Emission Factors for GHG Inventories data sheet.[7] Note that the carbon dioxide emission coefficient for Jet Fuel A was multiplied by a radiative forcing factor of 2.7 in order 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.[8]

BUSINESS TRAVEL

The business travel scope in this 2019 assessment is limited to the incomplete fleet fuel data in the section above and some 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 GHG assessment for this category is an underestimate. Better methods for capturing airline travel, independent of booking method, will be considered for the future.

Airline travel data for trips booked through the three primary VT-approved travel agencies for fiscal year 2019 was obtained from Lynn Meadows, Senior Travel Consultant in the Virginia Tech Controller's Office. At the time of this assessment, it was not possible to easily go back and get calendar year data

Vehicle Type	CO_2 (kg/unit)	CH_4 (g/unit)	N_2O (g/unit)	Unit
Passenger Car[A]	0.335	0.009	0.0080	vehicle-miles
Light-Duty Truck[B]	0.461	0.012	0.0100	vehicle-miles
Motorcycle	0.184	0.070	0.0070	vehicle-miles
Intercity Rail: Northeast Corridor[C]	0.058	0.0055	0.0007	pass-miles
Intercity Rail: Other Routes[C]	0.150	0.0117	0.0038	pass-miles
Intercity Rail: National Average[C]	0.113	0.0092	0.0026	pass-miles
Commuter Rail[D]	0.148	0.0123	0.0030	pass-miles
Transit Rail (i.e. Subway, Tram)E	0.099	0.0089	0.0013	pass-miles
Bus	0.053	0.0206	0.0009	passenger
Air Travel: Short Haul (<300 mi)	0.215	0.0077	0.0068	pass-miles
Air Travel: Medium Haul (≥300 mi<2300 mi)	0.133	0.0006	0.0042	pass-miles
Air Travel: Long Haul (≥2300 mi)	0.165	0.0006	0.0052	pass-miles

Weighted Emissions Factors (kg/passenger mi)
CH_4 0.000000685 | CO_2 0.154 | N_2O 0.00000487

Table 9. Airline Emission Factors

to match the time scope for the rest of this assessment. In the future, calendar-year data will be used. 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 mi), medium (≥300 and <2,300 mi) and short haul flights (<300 mi) based on the EPA carbon emission factors shown in Table 9 from the EPA Center for Corporate Climate Leadership website.[9]

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 Table 9, a weighted-average custom factor was calculated for this Tech data. The total CO_2, CH_4, and N_2O emissions (kg) for Virginia 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) for SIMAP.

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. This additional factor is multiplied by the emissions factor in SIMAP.[8]

SOLID WASTE AND WASTEWATER

Municipal Solid Waste (MSW) and Wastewater data came from the GHG 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 2019, VT produced 3,937 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 GHG credit for the avoided emissions due to the electricity generation.

In 2019, Tech sent 461,610,000 gals 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.

2019 Waste and Wastewater
Total MSW Produced
3,937 tons
Total Wastewater Produced
461,610,000 gals

AGRICULTURAL OPERATIONS: FERTILIZER, LIVESTOCK, AND LAND USE

sheep: 750 head
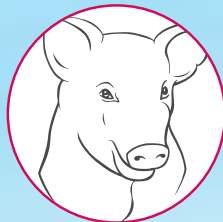
swine: 465 head
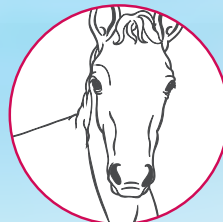
horses: 110 head

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

Virginia Tech has agricultural operations on campus which include 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 above.

Fertilizer applied on 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 as shown in Table 10. Liquid and solid applied manure data was provided in kilogals 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/gal assumed for the liquid manure. The percent nitrogen for the synthetic fertilizer and animal manure was assumed from common values in the literature.

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 Mix 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

Table 10. Agriculture Operation Fertilizer Analysis

Virginia 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 data, the Total Fertilizer Mass for the fertilizers was back-calculated. The SIMAP default emissions factors were used for the nitrogen to N_2O conversion. Fertilizer and animals contribute approximately 4.4% of the total VT GHG emissions, more than the emissions for the categories of commuting, buses, fleet fuels, or business air travel.

METHANE LEAKAGE

Methane, commonly known as natural gas, is a potent greenhouse gas with a GWP of 28. While natural gas is often discussed in news reports as a bridge fuel with lower GHG 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 GHG emissions of natural gas to be comparable to those for coal.[10] Including this GHG emission source in the updated VT Climate Action Plan was a major request by the VT 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.

Upstream Methane Leakage Estimate	Quantity (head)
Natural Gas Leak Rate (from literature)	2%
VT Direct Natural Gas (m³)	31,973,852
VT Indirect Natural Gas (from utility electricity)(m³)	13,320,324
Natural Gas Leakage (m³)	885,884
Natural Gas Mass Density (kg/m³)	0.70
Total Methane Mass Leakage	620,118

Table 11. Virginia Tech Natural Gas Leakage Estimate

The GHG emission data from methane leakage due to upstream operations associated specifically with natural gas delivered to 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%).[11] 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.[12]

Based on the average value of these two scientific studies, we used 2% leakage applied to all natural gas consumed by Virginia Tech in the Central Power Plant, Buildings, and Leased Spaces. The primary natural gas used by the utility to generate electricity was also included by considering the natural gas percentage of 21% from the APCO 2019 fuel mix[13] and an assumed utility power plant efficiency of 35%. This leakage value was multiplied by the total natural gas consumption volume, converted to mass based on the gas density at 20°C and 1 atm[14], and entered into SIMAP under the Category of Refrigerants and Chemicals. These emissions were manually adjusted to Scope 3 emissions per GHG protocols.

Results and Discussion

Scope	Source	CO_2 (kg)	CO_2 (mt CO_{2e})	CH_4 (kg)	CH_4 (mt CO_{2e})	N_2O (kg)	N_2O (mt CO_{2e})	GHG (mt CO_{2e})	GHG (%)
2	Purchased Electricity	123,257,006	123,257	11,898	333	2,172	576	124,166	44.2
1	VT Power Plant Steam	52,475,485	52,475	5,372	150	283	75	52,701	18.8
1	VT Power Plant Electricity	17,321,708	17,322	1,773	50	93	25	17,396	6.2
3	Upstream Methane Leakage	0	0	620	17,366	0	0	17,366	6.2
3	Faculty Commuting	13,873,467	13,873	749	21	486	129	14,023	5.0
3	Electricity T&D Losses	13,705,818	13,706	1,323	37	242	64	13,807	4.9
1	Fertilizer & Animals	0	0	384,544	10,767	6,104	1,618	12,385	4.4
3	Business Air Travel	9,155,116	9,155	15	0	107	28	9,184	3.3
1	Building Natural Gas	8,207,390	8,207	817	23	16	4	8,235	2.9
1	Fleet and Aviation Fuels	4,595,961	4,596	120	3	98	26	4,625	1.6
3	BT Bus System	3,025,873	3,026	9	0	9	2	3,029	1.1
3	Undergraduate Student Commuting	2,829,711	2,830	153	4	99	26	2,860	1.0
3	Graduate Student Commuting	927,065	927	50	1	33	9	937	0.3
3	Wastewater	0	0	0	0	752	199	199	0.1
3	Solid Waste	0	0	-4,724	-132	0	0	-132	0.0
			249,375		28,625		2,781	280,781	100%
	88.8% CO_2 + 10.2% CH_4 + 1.0% N_2O = 100% Virginia Tech GHG Emissions								

Table 12. SIMAP GHG Emissions Results

All GHG emissions results were calculated by SIMAP based on the inventory data and emissions factors detailed in the previous sections. The resulting emissions are shown in Table 12, 13, and Figure 3.

The total estimated GHG emissions for this assessment are 280,781 metric tons carbon dioxide equivalent (mt CO2e). The scope 2 utility electricity is the largest emission category at 44%. The direct university emissions in scope 1 account for 34%. The indirect emissions of scope 3 are 22% of the total carbon footprint. 70% of these scope 3 emissions are due to the expanded scope elements of electricity T&D losses, upstream methane leakage, business air travel, and the BT bus system.

Breaking this down by GHG chemical, 89% of these emissions are due to CO_2, 10% due to CH_4, and 1% due to N_2O. From a source perspective, 70% of the
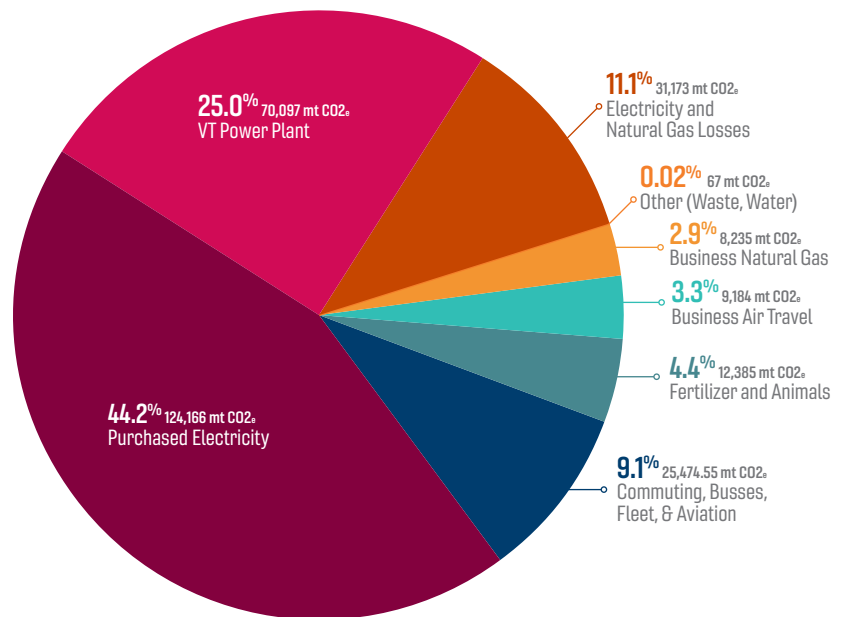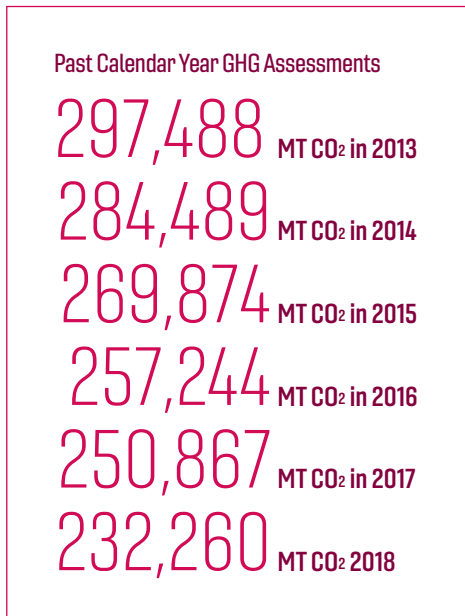

Figure 3. SIMAP GHG results by category

Scope	GHG (mt CO2e)	GHG (%)
1	95,342	34.0
2	124,166	44.2
3	61,273	21.8
280,781		**100%**

Table 13.

Past Calendar Year GHG Assessments

297,488 MT CO2 in 2013

284,489 MT CO2 in 2014

269,874 MT CO2 in 2015

257,244 MT CO2 in 2016

250,867 MT CO2 in 2017

232,260 MT CO2 2018

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% and not under the control of the university, though these values scale down linearly as energy use is reduced. Transportation fuels account for 13% of emissions, with half of these attributed to faculty/staff/student 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 due to higher electric vehicle efficiencies and more renewable energy in the electrical grid.

For context, previous Virginia Tech GHG assessment results are shown to the left, but the 2019 results shouldn't be directly compared given the significant changes in the method and expanded scope of this assessment. The main changes are adding leased building space, the BT Bus system, RECs, business air travel, electricity T&D losses, and methane leakage to the assessment scope. 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 RECs which reduced the overall electricity emissions.

Conclusions

The 2019 GHG Emissions Assessment was completed during Fall semester 2020 using the expanded scope and methods recommended by the GHG Subcommittee of the Spring 2020 Climate Action Committee (CAC). All recommended scope elements are included in this assessment except for Dining/Food Emissions and carbon sequestration by Virgina Tech agricultural/forestry lands and the campus tree canopy. This report is a critical piece of the Climate Action Plan since it provides detailed data for future decisions and plans to reduce carbon emissions associated with Virgina Tech.

This was the first year using Sustainability Indicator Management and Analysis Platform (SIMAP) software instead of the Facilities Master Spreadsheet. The Master Spreadsheet is still one of the main ways that Facilities compiles utility electricity and natural gas and Central Steam plants fuels and data.

Data review and analysis was done by an Independent Study course advised by Dr. Sean McGinnis, Director of the Green Engineering Program, with help from Virginia Tech staff, faculty, and students. As noted, in some areas like fleet fuels and business travel, data collection would be easier and more accurate with updated operational procedures.

A future project is also recommended to determine the best way to handle and analyze the large amount of dining/food data which is available from Dining Services to include estimates of upstream food emissions.

References

1   World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), Greenhouse Gas 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 Sinks epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

3   GHG Protocol Website, Global Warming Potential Values, bit.ly/GHGProtocolGlobalWarmingPotentialValues16

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

6   AEP-APPALACHIAN POWER COMPANY (APCO-Virginia and West Virginia Combined), 2016 Analysis of System Losses, Management Applications Consulting, Inc., February 2018.

7   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

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

9   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

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

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

12 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.

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

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

Appendices

APPENDIX 1: VT GHG DATA SOURCE SUMMARY TABLE

Category	Data Source	Contact Information
Main Campus Electricity, Natural Gas, and Steam Plant Fuels	VT Facilities and Master Spreadsheet	**Lowell Jessee** Energy Engineer **Todd Robertson** Power Plant Operation Manager **Daniel Webb** Student **Conor Doane** Student
Leased Space Electricity and Natural Gas	Utility Data VT Leased Space Spreadsheet	**Steve Johnston** Enterprise Applications and Space Data Manager
Electricity Emission Factors	APCO direct contact Emissions factor values for 2019	**William Rogers** APCO Customer Account Manager
Renewable Energy Credits (RECs)	Virginia Tech Electrical Service (VTES)	**Rob Glenn** VTES Director of Electrical Services
Fleet Fuels	Virginia Tech Fleet Services Only Fuels dispensed at Fleet Services	**Arben Abazi** Fleet Dispatcher and Service Agent
Aviation Fuels	Virginia Tech Air Transportation Services	**Melissa Ball** Flight Operations Manager
Transit Bus Fuels	Blacksburg Transit (BT)	**Erik Olsen** BT Transit Transportation Planner
Commuting Permits and Fuels	Virginia Tech Transportation Services Commuter Survey	**Pam Tate** Parking Services Assistant Manager **Sean McGinnis** Director of VT Green Engineering Program
Airline Travel	Airline City Pair Spreadsheets Data only for travel agency airline bookings	**Lynn Meadows** Senior Travel Consultant
Agriculture	Virginia Tech Agricultural Operations	**Jody Booze-Daniels** CALS Research Associate **Dr. Greg Evanylo** CSES Professor
Solid Waste	Virginia Tech Master Spreadsheet	**Teresa Sweeney** Program Consultant and Engagement Specialist
Wastewater	Virginia Tech Waste and Wastewater Master Spreadsheet	**Michael Vaught** Blacksburg-VPI Sanitation Authority Executive Director
Compost	Virginia Tech Office of Sustainability	**Nathan King** Sustainability Manager **Denny Chochrane** Director of Sustainability
Enrollment	Virginia Tech Office of Analytics and Institutional Effectiveness	**Roxanne Gile** Director of Strategic Analysis

Source	CO$_2$	CH$_4$	N$_2$O	NO$_x$
SIMAP 2019 Emissions Values				
SCOPE 1				
Stationary Fuels				
Coal (steam coal)	18.39 kg CO$_2$/short ton	0.203 kg CH$_4$/short ton	0.03005 kg N$_2$O/short ton	9.46 kg NO$_x$/short ton
Distillate Bioheat	10.02 kg CO$_2$/gal	0.00153 kg CH$_4$/gal	0.0000858 kg N$_2$O/gal	0.00508 kg NO$_x$/gal
Distillate Oil (#1-4)	10.16 kg CO$_2$/gal	0.00145 kg CH$_4$/gal	0.000087 kg N$_2$O/gal	0.00515 kg NO$_x$/gal
Ethanol	5.75 kg CO$_2$/gal	0.0000567 kg CH$_4$/gal	0.000257 kg N$_2$O/gal	N/A
Grass Pellets	1639.51 kg CO$_2$/short ton	5.53 kg CH$_4$/short ton	0.0738 kg N$_2$O/short ton	0.607 kg NO$_x$/short ton
Incinerated Waste	380 kg CO$_2$/short ton	0 kg CH$_4$/short ton	0.151 kg N$_2$O/short ton	2.47 kg NO$_x$/short ton
LPG (Propane)	5.17 kg CO$_2$/gal	0.000883 kg CH$_4$/gal	0.000053 kg N$_2$O/gal	0.00315 kg NO$_x$/gal
Natural Gas	53.02 kg CO$_2$/mmbtu	0.00528kg CH$_4$/mmbtu	0.0001060 kg N$_2$O/mmbtu	0.0341 kg NO$_x$/mmbtu
Residual BioHeat	10.91 kg CO$_2$/gal	0.00153 kg CH$_4$/gal	0.0000920 kg N$_2$O/gal	0.00545 kg NO$_x$/gal
Residual Oil (#5-6)	11.24 kg CO$_2$/gal	0.00158 kg CH$_4$/gal	0.0000948 kg N$_2$O/gal	0.00561 kg NO$_x$/gal
Wood Chips	1639.51 kg CO$_2$/short ton	5.53 kg CH$_4$/short ton	0.0738000 kg N$_2$O/short ton	0.607 kg NO$_x$/short ton
Wood Pellets	1639.51 kg CO$_2$/short ton	5.53 kg CH$_4$/short ton	0.0738000 kg N$_2$O/short ton	0.607 kg NO$_x$/short ton
Transport Fuels				
B100	9.45 kg CO$_2$/gal	0.0000296 kg CH$_4$/gal	0.0000308 kg N$_2$O/gal	0.0446 kg NO$_x$/gal
B20	10.02 kg CO$_2$/gal	0.0000296 kg CH$_4$/gal	0.0000308 kg N$_2$O/gal	0.0446 kg NO$_x$/gal
B5	10.13 kg CO$_2$/gal	0.0000296 kg CH$_4$/gal	0.0000308 kg N$_2$O/gal	0.0446 kg NO$_x$/gal
Diesel Fleet	10.16 kg CO$_2$/gal	0.0000296 kg CH$_4$/gal	0.0000308 kg N$_2$O/gal	0.0446 kg NO$_x$/gal
E85 Fleet	6.49 kg CO$_2$/gal	0.00104 kg CH$_4$/gal	0.00119 kg N$_2$O/gal	0.0131 kg NO$_x$/gal
Gasoline Fleet	8.59 kg CO$_2$/gal	0.000463 kg CH$_4$/gal	0.000301 kg N$_2$O/gal	0.0134 kg NO$_x$/gal
Natural Gas Fleet	53.02 kg CO$_2$/mmbtu	0.014 kg CH$_4$/mmbtu	0.000412 kg N$_2$O/mmbtu	0.0575 kg NO$_x$/mmbtu
Fertilizer				
Organic Fertilizer	N/A	N/A	0.01020kg N$_2$O/lb	N/A
Synthetic Fertilizer	N/A	N/A	0.00944kg N$_2$O/lb	N/A
Animals				
Beef Cows	N/A	76.40 kg CH$_4$/head	0.45 kg N$_2$O/head	N/A
Dairy Cows	N/A	217.00 kg CH$_4$/head	1.46kg N$_2$O/head	N/A
Goats	N/A	5.48kg CH$_4$/head	0.0476 kg N$_2$O/head	N/A
Horses	N/A	20.50 kg CH$_4$/head	0.124 kg N$_2$O/head	N/A
Poultry	N/A	0.0621 kg CH$_4$/head	0.00245 kg N$_2$O/head	N/A
Sheep	N/A	8.57 kg CH$_4$/head	0.19 kg N$_2$O/head	N/A
Swine	N/A	12.60 kg CH$_4$/head	0.0901 kg N$_2$O/head	N/A
SCOPE 2				
Purchased Electricity	unhsimap.org/cmap/resources/references/53		Coming Soon	Coming Soon
Purchased Steam	Coming Soon			
Chilled Water	Coming Soon			

SIMAP 2019 Emissions Values				
Source	CO_2	CH_4	N_2O	NO_x
SCOPE 3				
Commuting				
Automobile	0.36 kg CO_2/passenger mi	0.0000192 kg CH_4/passenger mi	0.0000125 kg N_2O/passenger mi	0.000556 kg NO_x/passenger mi
Bike	0 k CO_2/passenger mi	0 kg CH_4/passenger mi	0 kg N_2O/mi	0 kg NO_x/passenger mi
Carpool	0.18 kg CO_2/passenger mi	0.00000962 kg CH_4/passenger mi	0.00000625 kg N_2O/passenger mi	0.000278 kg NO_x/passenger mi
Commuter Rail	0.15 kg CO_2/ passenger mi	0.00000569 kg CH_4/passenger mi	0.00000108 kg N_2O/passenger mi	0.0000452 kg NO_x/passenger mi
Light Rail	0.16 kg CO_2/passenger mi	0.00000603 kg CH_4/ passenger mi	0.00000201 kg N_2O/passenger mi	0.000158 kg NO_x/passenger mi
Public Bus	0.33 kg CO_2/passenger mi	0.0000143 kg CH_4/passenger mi	0.000000994 kg N_2O/passenger mi	0.0014 kg NO_x/passenger mi
Walk	0 kg CO_2/mi	0 kg CH_4/mi	0 kg N_2O/mi	0 kg NO_x/passenger mi
Business Travel and Study Abroad				
Air Travel	0.16 kg CO_2/passenger mi	0.00000476 kg CH_4/passenger mi	0.0000049 kg N_2O/passenger mi	0.000195 kg NO_x/passenger mi
Alternative Fuel Bus	N/A	N/A	N/A	N/A
Charter Bus - CNG	2.52 kg CO_2/vehicle mi	0.000175 kg CH_4/vehicle mi	0.00197 kg N_2O/vehicle mi	N/A
Charter Bus - Diesel	3.11 kg CO_2/vehicle mi	0.00408 kg CH_4/vehicle mi	0.00185 kg N_2O/vehicle mi	N/A
Personal Milage Reimburse	0.36 kg CO_2/passenger mi	0.0000192 kg CH_4/passenger mi	0.0000125 kg N_2O/passenger mi	0.000556 kg NO_x/passenger mi
Public Bus	0.33 kg CO_2/passenger mi	0.000000955 kg CH_4/passenger mi	0.000000994 kg N_2O/passenger mi	0.0014 kg NO_x/passenger mi
Taxi/Ferry/Rental Car	0.36 kg CO_2/passenger mi	0.0000192 kg CH_4/passenger mi	0.0000125 kg N_2O/passenger mi	0.000556 kg NO_x/passenger mi
Train	0.12 kg CO_2/passenger mi	0.000000346 kg CH_4/passenger mi	0.00000036 kg N_2O/ passenger mi	0.000737 kg NO_x/passenger mi
Student Travel to/from Home				
Air Travel	0.16 kg CO_2/passenger mi	0.00000476 kg CH_4/passenger mi	0.0000049 kg N_2O/passenger mi	0.000195 kg NO_x/passenger mi
Automobile	0.36 kg CO_2/passenger mi	0.0000192 kg CH_4/passenger mi	0.0000125 kg N_2O/passenger mi	0.000556 kg NO_x/passenger mi
Carpool	0.18 kg CO_2/passenger mi	0.00000962 kg CH_4/passenger mi	0.00000625 kg N_2O/passenger mi	0.000278 kg NO_x/passenger mi
Public Bus	0.33 kg CO_2/passenger mi	0.000000955 kg CH_4/passenger mi	0.000000994 kg N_2O/passenger mi	0.0014 kg NO_x/passenger mi
Train	0.12 kg CO_2/passenger mi	0.000000346 kg CH_4/passenger mi	0.00000036 kg N_2O/passenger mi	0.000737 kg NO_x/passenger mi
Food				
Food	unhsimap.org/unhsimap.org/carbonreferencescope3food unhsimap.org/unhsimap.org/nitrogenreferencescope3food			
Waste and Wastewater				
Incinerated Waste: Mass Burn	-40 kg CO_2/short ton	N/A	N/A	N/A
Incinerated Waste: Refuse Derived Fuel (RDF)	0 kg CO_2/short ton	N/A	N/A	N/A
Solid Waste: Landfilled Waste-CH_4 Recovery and Electric Generation	0 kg CO_2/short ton	-1.2 kg CH_4/short ton	N/A	N/A
Solid Waste: Landfilled Waste-CH_4 Recovery and Flaring	0 kg CO_2/short ton	12.4 kg CH_4/short ton	N/A	N/A
Solid Waste: Landfilled Waste-No CH_4 Recovery	0 kg CO_2/short ton	124 kg CH_4/short ton	N/A	N/A
Wastewater: Centeral Treatment System-Aerobic	0 kg CO_2/short ton	0 kg CH_4/gal	0.00000163 kg N_2O/gal	N/A
Wastewater: Central Treatment System-Anaerobic	0 kg CO_2/short ton	0.00034 kg CH_4/gal	0.00000163 kg N_2O/gal	N/A
Wastewater: Central Treatment System-Anaerobic Digestion	0 kg CO_2/short ton	0.00000122 kg CH_4/gal	0.00000163 kg N_2O/gal	N/A
Wastewater: Septic System	0 kg CO_2/short ton	0.000213 kg CH_4/gal	0.00000148 kg N_2O/gal	N/A

This survey is anonymous and will be used by the VT Climate Action Committee (CAC) Working Group to assess the greenhouse gas (GHG) emissions from VT faculty/staff/student commutes to and from campus. it will also help the Working Group develop plans and options for reducing these emissions in the future. Answer these questions for your typical commute during the last academic year. Use information from last spring rather than this spring due to the virus-related disruption to the semester.

Choose the category which best represents your role on campus

◯ Faculty

◯ Staff/Administration

◯ Undergraduate Student

◯ Graduate Student

◯ Wage Worker

◯ Other

[   ]

Estimate the percent of the time, out of 100% that you COMMUTE to and from CAMPUS from HOME using each of the following transportation modes

	0	10	20	30	40	50	60	70	80	90	100	
Car (driving alone)												0
Blacksburg Transit (BT)												0
Carpool/Vanpool												0
Smart Way Bus												0
Motorcycle/Moped												0
Bicycle												0
e-Scooter/ e-Skateboard												0
Walk												0
Other												0

[   ]

Total: **0**
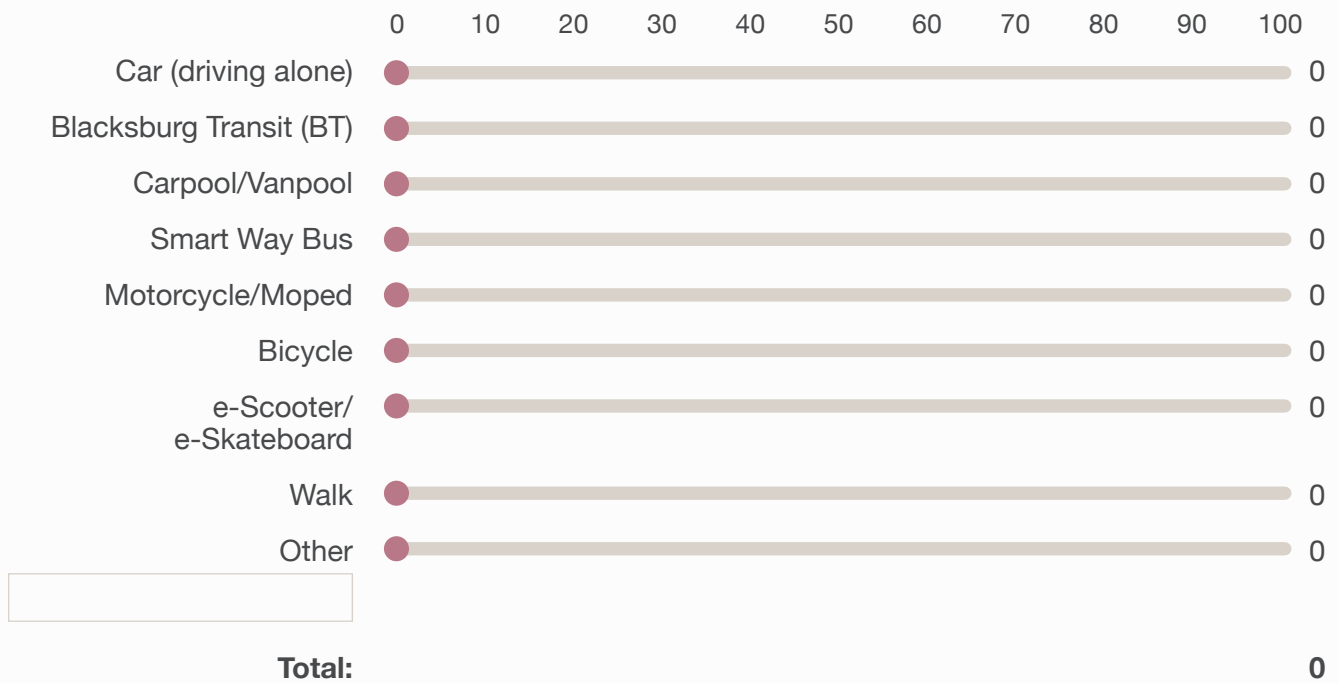
If you commute to campus by car, which type of parking permit do you have?

○ No permit

○ Resident

○ Graduate Student

○ Faculty/Staff

○ Commuter

○ Wage

○ Other

[   ]

On average, how many day per week do you drive to campus?

○ 0

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ 7

On average, how many driving round-trips do you make per day from your residence?

○ 1

○ 2

○ 3

○ 4

○ 5

○ Other

[   ]

On average, what is the ROUNDTRIP miage from your residence to campus and back? Please report only one pecimal place, for example enter 3.2 if you like 1.6 mis from campus using your typical route to your typical parking location. You can use Google maps or other mapping software if you don't know this distance.

[ ]

What is the make of the car your drive to campus most often (Ford, Honda, etc.)?

[ ]

What is the model of the car you drive to campus most often (Camry, Focus, Silverado etc.)?

[ ]

Select the manufacturing year for the car you drive to campus most often (make your best guess if you don't know for sure)?

[ ]

What fuel does your car use?

◯ Gasoline

◯ Diesel

◯ Electricity

◯ Other (biofuels, natural gas, etc.)

[ ]