

2021

HARRISONBURG GHG EMISSIONS REPORT



CITY OF HARRISONBURG, VIRGINIA

**ICLEI GOVERNMENT EMISSIONS INVENTORY
2021 SUMMARY REPORT**

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EXECUTIVE SUMMARY

The City of Harrisonburg, Virginia, greenhouse gas (GHG) emissions inventory was completed for the calendar year 2021 and compared to the previous analysis for 2016 (baseline year) and 2019. This report is part of Phase 2 of the City of Harrisonburg's Environmental Action Plan (EAP). The GHG emissions inventory was completed at both the Municipal and Community levels.

The scope of the Municipal inventory includes energy (electricity, natural gas, and fuel oil) for City buildings/facilities, electricity for street/traffic lights, diesel/gasoline fuels for City fleet vehicles/equipment and City Transit buses. This scope is focused on areas in which the City has some control of decisions that can affect GHG emissions.

100-yr and 20-yr GWP values were used in the analysis to provide both shorter and longer term perspectives. These different time horizons account for the different lifetime of GHGs in the atmosphere. The primary difference in the results is the stronger contribution of methane, mainly from leakage in natural gas distribution, for the 20-yr analysis. 100-yr GWP analyses dominate most reports produced by governments and corporations to meet the Paris Agreement international treaty goal to limit global average temperatures to below 2.0, and preferably to 1.5 degrees Celsius, compared to pre-industrial levels. Given the closing window to meet this goal, there is increasing discussion to promote the use of 20-yr GWP analyses and focus more on methane reductions.

The scope of the Community inventory includes energy (electricity and natural gas) split among the following major sectors: Residential, Commercial, Industrial, Municipal, Water & Sewer, and James Madison University (JMU). Community inventory also includes estimated fuel use (gasoline and diesel) for vehicle travel within the City boundaries based on Virginia Department of Transportation (VDOT) traffic counts. GHG emissions from Solid Waste, Water Treatment, and Waste Water Treatment are included in the Community Inventory as well. This scope is focused on the broader Community GHG emissions, which are only indirectly affected by City policies/initiatives and controlled more directly by the activities and behavior of the community as a whole and its members individually.

Total Municipal GHG emissions in 2021 for Harrisonburg were 20,600 metric tons, a 5.2% decrease from the 2016 baseline level using 100-yr GWP values. Buildings/facilities accounted for 39% of these emissions and the dominant fuel source for the City was electricity at 51%. School operations including electricity, natural gas, fuel oil, and diesel fuel (school buses) contribute 30% of all Municipal GHG emissions.

Total Community GHG emissions in 2021 for Harrisonburg were 609,000 metric tons, a 3.4% decrease from the 2016 baseline level using the 100-yr GWP values. The Commercial and Transportation sectors accounted for 30% and 28% of these emissions, respectively, and the dominant fuel source for the Community emissions was electricity at 38%. The Municipal sector accounted for approximately 3.4% of the total Community GHG emissions.

For the 20-yr GWP analysis, total Community GHG emissions in 2021 were 806,000 metric tons, a 1.0% decrease. This smaller reduction in GHG emissions in the 20-year timeframe is primarily due to the higher relative GWP of methane from natural gas leakage and solid waste landfill gas.

This initial report can serve as the basis for further discussions and planning among key stakeholders in both the City and Community to develop action plans for future GHG emissions reductions.

1. INTRODUCTION

This report details both the Municipal (City operations) and Community Greenhouse Gas (GHG) emissions for the City of Harrisonburg, VA, for the calendar year 2021. These results are compared to the previous analyses for 2016 (baseline year) and 2019. These emissions are estimated based on the inventory of energy and fuel use for Harrisonburg. The 2020 data set was not considered to be representative of a typical year due to the pandemic based on the changes from normal city operations that were associated with it. In compiling and analyzing the 2021 data, several small errors were found in the 2016/19 assessment. These errors have been fixed and are noted in this report – in data tables these updated data and values are indicated by red text.

This report is part of Phase 2 of the City of Harrisonburg’s Environmental Action Plan (EAP). The development of the EAP will be completed in three phases (1, 2, and 3). The EAP consists of six focus areas: (1) Buildings and Energy, (2) Land Use and Green Space, (3) Regional Food Systems, (4) Sustainable Transportation, (5) Waste Reduction and Recycling, and (6) Water Resources. Phase 1 describes goals, co-benefits, and strategies, and identifies tasks and responsible parties. Phase 1 of the EAP was presented to City Council and adopted on January 14, 2020. Phase 2 compiles an inventory of municipal and community activities and links them to energy and GHG emissions to develop a baseline to be used for measuring progress towards achieving goals in the future. This particular analysis includes focus areas (1), (4), and (5). GHG emissions for focus areas (2), (3), and (6) are generally much harder to measure and with fewer direct GHG emissions and are therefore not part of the scope of this analysis. Land use emissions are complex and depend on many factors including the type of land and specific changes from one particular landscape to another. Adding trees to increase the tree canopy also reduces emissions indirectly by shading buildings and lower the urban heat island effects, which results in less cooling needed during warmer months. This is in addition to direct effects of trees acting as GHG emission sinks as carbon dioxide is removed from the air as part of the photosynthesis process. Because trees grow slowly and sequester carbon from the atmosphere, reducing the removal of trees in cities is as important as planting new trees. These baseline indicators provide a snapshot of the current conditions and can be useful for setting actionable and measurable targets. During Phase 3, the City will consider baseline inventory data and GHG emissions to establish targets with statements that define the desired change by a specific year.

Greenhouse gases (GHGs) are chemicals in the atmosphere that absorb radiation and therefore warm the atmosphere and the planet.¹ These gases, which include carbon dioxide, methane, and various refrigerants, are released into the atmosphere by various human activities. GHGs are characterized by a Global Warming Potential (GWP), which quantifies the potential of these chemicals to absorb heat compared to carbon dioxide over a specific time period. Carbon dioxide (CO₂) is the dominant GHG in the atmosphere by mass and is emitted due to combustion of fossil fuels including coal, natural gas, heating oil, gasoline, and diesel fuel. Methane emissions are much smaller in amount, but this chemical has a much larger GWP (see table 1) so contributes more significantly than one would expect based only on the amount. Although not the focus of this analysis, the combustion of fossil fuels also leads to additional air pollution including Criteria Air Pollutants (CAPs), which can also harm human health and the environment.

GHGs are strongly linked through scientific research modeling to increasing global temperatures and have been increasing since the industrial revolution. Many cities, states, and countries are developing plans to reduce GHGs and mitigate the expected environmental, economic, and health impacts of global warming and climate change. According to climate scientists and based on thousands of

research studies, the time window for reducing GHG emissions and thereby minimizing the negative effects on human health, the environment, and global economic systems is closing.

The primary goals of a GHG inventory are to understand the sources of GHG emissions within both the community at large and across a City's municipal operations. This information is critical to make effective changes to both policy and practice at the municipal and community levels to reduce these emissions. Without an understanding of the specific sources and magnitude of these emissions, it is impossible to develop plans that are both feasible and cost effective for GHG reductions.

Effectively preparing for and responding to current and projected climate change requires an ongoing evaluation and a series of action steps, not a one-time assessment. It calls on our community to adopt policies and practices that make environmental sustainability and resilience a consideration in all activities and actions taken by our community. It also calls on us to strengthen existing efforts and build partnerships throughout the community to reduce Harrisonburg's vulnerability to the changing environment. The development of the EAP is designed to accomplish this goal. The EAP acknowledges existing city plans, programs and strategies, and builds upon them by proposing measures to accelerate advancements in sustainability, of which economic vitality, environmental protection, and health and well-being are collectively considered to be critical pieces of achieving sustainability goals and reducing greenhouse gas emissions. Adopting and implementing the EAP helps the City support global targets for a stable climate and a resilient community.

There is always a balance between the accuracy/detail and time/effort in this type of analysis. Enough detail is required to identify areas of concern and action, but too much detail can take additional time and effort that either does not provide the necessary resolution or is not required to make broad decisions.

2. METHODOLOGY, SCOPE AND ASSUMPTIONS

The ICLEI ClearPath online software analysis (<https://clearpath.iclei.usa.org/>) was used for this analysis. The baseline year data in this report is 2016 and 2019 data has been analyzed and reported as well. The 2016/2019 analysis uses the 100-year global warming potentials (GWP) from the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (AR5). Table 1 shows the GWPs for the most common of the emission chemicals for both the 20-yr and 100-yr timeframes.²

The 100-yr time horizon and the associated GWP values have been the typical recommendation by the IPCC and most other major reporting platforms recommend that you calculate your footprint using the 100-year GWP for GHG analyses and decision-making. However, continuing research and climate modeling are suggesting that a shorter time horizon may be a better choice for local, national, and international government policies and actions given the scientific recommendations of 50% GHG reductions by 2030 and 100% reductions by 2050. As seen in Table 1, the main difference in the GHG values for the 20-yr time horizon is a much stronger contribution for methane since it has a shorter lifetime in the atmosphere. This means that methane reductions will have a more significant effect on climate change compared to carbon dioxide over this shorter time frame. Note that this does not change the overall climate impact at longer time frames.

Chemical	IPCC AR5: 20-yr GWP (kg CO2e/kg)	IPCC AR5: 100-yr GWP (kg CO2e/kg)
Carbon Dioxide (CO ₂)	1	1
Methane (CH ₄)	84	28
Nitrous Oxide (N ₂ O)	264	265

Table 1 – Global Warming Potentials from the IPCC 5th reports.

3. MUNICIPAL AND COMMUNITY INVENTORY DATA

3a. Electricity

Most of the electricity data was provided by the Harrisonburg Electric Commission (HEC). Municipal Electricity data was provided based on HEC metered accounts in detailed spreadsheets with usage by departments and by month. Grid loss was estimated based on the SRVC regional grid from the EPA eGrid database.³ The electricity data was sorted by department and a detailed dataset is provided in Appendix 1. Additional electricity data for the Raw Water Pumping Station, Water Treatment Plant, and the Harrisonburg Rockingham Regional Sewage Authority (HRRSA) was added to the HEC data from Dominion Power accounts since these facilities are located outside of the City limits. Because these facilities serve more than just the City, their electricity totals were allocated based on the fraction of City customers. These values were 82% and 56.4%, respectively, for water pumping and treatment for the Sewer Authority in 2021. In the 2016 baseline year, the percentage of water and sewage treatment for the City were 85% and 63%.

A summary of all of the electricity data is provided in Table 2 and in the pie chart in Figure 1. Note that the pie chart does not include categories less than 1%. Electricity is dominated by *Schools* with 36% of the total usage in 2021 followed by Sewer and Water with a combined contribution of 36.9%. Overall, electricity usage decreased 2.2% from 2019 but is 1.4% higher than the 2016 baseline. It should be noted that Bluestone Elementary School was added in 2017 (103,700 ft²) and Elon Rhodes Early Learning Center was added in 2017 (16,000 ft²). The difference calculated in the final columns of Table 2, and throughout the report, is the current year value minus the previous value divided by the previous value, which gives a percent increase or decrease from another year.

DEPARTMENT/FUNCTION	2016		2019		2021		Difference 2021 vs 2016 (%)
	kWh	% of Total	kWh	% of Total	kWh	% of Total	
SCHOOLS	11,364,115	36.3%	12,584,293	38.7%	11,439,828	36.0%	0.7%
SEWER AUTHORITY	7,260,657	23.2%	7,304,352	22.5%	7,951,502	25.0%	9.5%
WATER DEPT, TREATMENT, & PUMPING	3,524,084	11.2%	3,442,868	10.6%	3,775,230	11.9%	7.1%
TRAFFIC & STREET LIGHTS	3,026,731	9.7%	3,041,823	9.4%	2,998,843	9.4%	-0.9%
RECREATION DEPT	1,770,972	5.6%	1,771,940	5.5%	1,520,684	4.8%	-14.1%
FIRE DEPT	1,621,085	5.2%	1,777,509	5.5%	1,682,096	5.3%	3.8%
TRANSPORTATION DEPT	1,088,028	3.5%	891,593	2.7%	742,191	2.3%	-31.8%
COMMUNITY DEVELOPMENT*	790,385	2.5%	771,089	2.4%	789,400	2.5%	-0.1%
PUBLIC WORKS	375,779	1.2%	410,153	1.3%	405,317	1.3%	7.9%
PARKING SERVICES	264,139	0.8%	238,848	0.7%	226,148	0.7%	-14.4%
EMERGENCY COMMUNICATIONS CENTER (HREC)	189,058	0.6%	217,225	0.7%	204,618	0.6%	8.2%
CENTRAL STORES	65,086	0.2%	46,264	0.1%	36,391	0.1%	-44.1%
POLICE DEPT	6,819	0.02%	10,014	0.03%	10,878	0.03%	59.5%
TOTALS	31,346,938	100%	32,507,971	100%	31,783,126	100%	1.4%
ELECTRICITY GRID LOSS (%)	4.5%		5.1%		5.3%		
ELECTRICITY GRID LOSS (4.5%)	1,410,612		1,657,907		1,684,506		

*City Hall Complex

Table 2 – Harrisonburg Municipal Electricity Usage by Department/Function

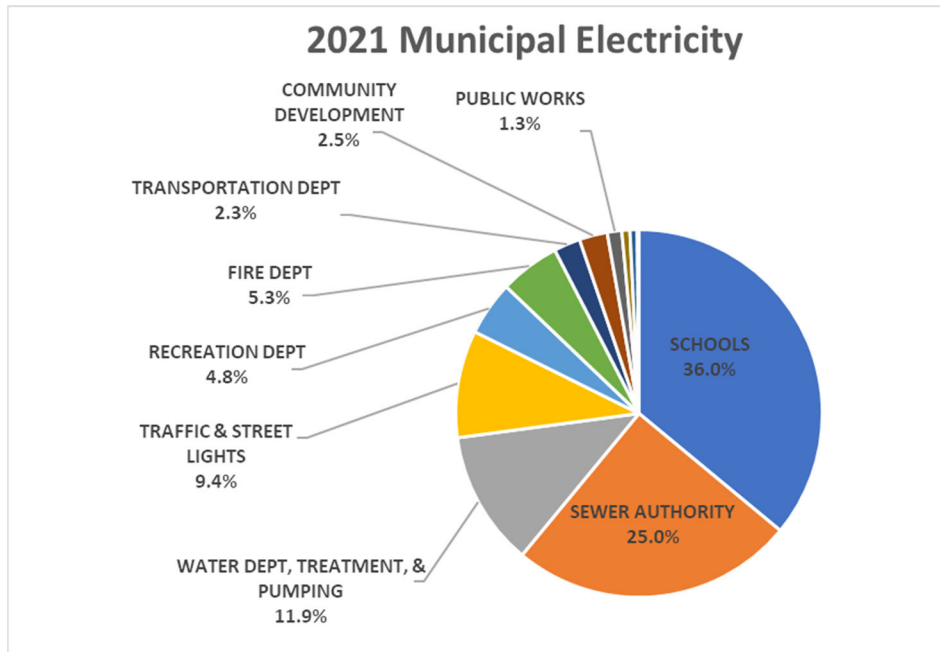


Figure 1 – Harrisonburg 2021 Municipal Electricity Pie Chart by Department/Function

As the largest electricity user, the Schools category for electricity usage was further broken down in Table 3 and Figure 2. Harrisonburg High School used 32% of the school system electricity in 2021. School system electricity increased approximately less than 1% from 2016 to 2021, with more than a 9% decrease from 2019. Note that Thomas Harrison Middle School also has a relatively small 2.4 kW Skystream wind turbine which generates electricity that offsets this school’s electricity usage. Wind speed and energy-generation data for this wind turbine can be found at https://openei.org/wiki/Thomas_Harrison_Middle_School_Wind_Project. This turbine has generated approximately 22,000 kWh to date.

School Summary			2016		2019		2021		2021 (%)	Δ 2016	Δ 2019
Account	School	Address	kWh	Total	kWh	Total	kWh	Total			
13653-27	Harrisonburg High School	1001 GARBERS CHURCH RD	1,324,800		1,469,760		1,202,880				
13653-28	Harrisonburg High School	1001 GARBERS CHURCH RD	1,826,880		2,322,240		2,148,480				
13653-29	Harrisonburg High School Stadium	1001 GARBERS CHURCH RD	178,944		188,544		139,776				
13653-35	Harrisonburg High School	1001 GARBERS CHURCH RD	17,161		35,931		31,018				
13653-36	Harrisonburg High School	1001 GARBERS CHURCH RD	17,920		54,160		40,960				
13653-38	Harrisonburg High School	1001 GARBERS CHURCH RD	-		54,240		37,200				
13653-39	Harrisonburg High School	1001 GARBERS CHURCH RD	-		26,960		23,680				
13653-40	Harrisonburg High School	1001 GARBERS CHURCH RD	-		24,800		24,000				
13653-41	Harrisonburg High School	1001 GARBERS CHURCH RD	-	3,365,705	-	4,176,635	27,815	3,675,889	32.1%	9.2%	-12.0%
13653-33	Smithland Elementary School/Skyline Middle School/Elon Rhodes Early Learning Center	470 LINDA LN	2,344,320	2,344,320	2,453,760	2,453,760	2,365,440	2,365,440	20.7%	0.9%	-3.6%
13653-19	Thomas Harrison Middle School	1311 W MARKET ST	1,819,200	1,819,200	1,350,720	1,350,720	1,080,000	1,080,000	9.4%	-40.6%	-20.0%
13653-6	Stone Spring Elementary School	1575 PEACH GROVE AVE	1,008,960		1,123,200		987,840				
13653-7	Stone Spring Elementary School	1575 PEACH GROVE AVE	16,290		32,443		13,305				
13653-8	Stone Spring Elementary School	1575 PEACH GROVE AVE	66,435		79,557		63,260				
13653-30	Stone Spring Elementary School	1575 PEACH GROVE AVE	34,726	1,126,411	43,742	1,278,942	44,371	1,108,776	9.7%	-1.6%	-13.3%
13653-14	Spotswood Elementary School	375 S CARLTON ST	191,760		193,000		192,560				
13653-15	Spotswood Elementary School	375 S CARLTON ST	563,520		622,560		535,120				
13653-16	Spotswood Elementary School	375 S CARLTON ST	46,257		47,627		55,387				
13653-17	Spotswood Elementary School	400 MOUNTAIN VIEW DR	27,297	828,834	21,047	884,234	16,948	800,015	7.0%	-3.5%	-9.5%
13653-3	Keister Elementary School	100 MARYLAND AVE	514,560		516,480		524,160				
13653-4	Keister Elementary School	100 MARYLAND AVE	101,777		93,023		104,588				
13653-5	Keister Elementary School	100 MARYLAND AVE	222,240	838,577	237,840	847,343	230,640	859,388	7.5%	2.5%	1.4%
13653-20	Waterman Elementary School	451 CHICAGO AVE SEC LIGH	6,300		6,300		6,300				
13653-21	Waterman Elementary School	451 CHICAGO AVE	714,240		718,560		709,200				
13653-22	Waterman Elementary School	451 CHICAGO AVE	52,785		55,653		52,166				
13653-23	Waterman Elementary School	451 CHICAGO AVE	46,943	820,268	47,726	828,239	51,634	819,300	7.2%	-0.1%	-1.1%
13653-37	Bluestone Elementary School	750 GARBERS CHURCH RD	-		536,100	536,100	516,300	516,300	4.5%	-3.7%	-6.0%
13653-34	School Board Office	1 COURT SQ	220,800	220,800	228,320	228,320	214,720	214,720	1.9%	-2.8%	-6.0%
Totals			11,364,115	11,364,115	12,584,293	12,584,293	11,439,828	11,439,828	100%	0.7%	-9.1%

* Bluestone Elementary School and Elon Rhodes Early Learning Center first opened in August 2017

Table 3 – Harrisonburg School Electricity Usage by School

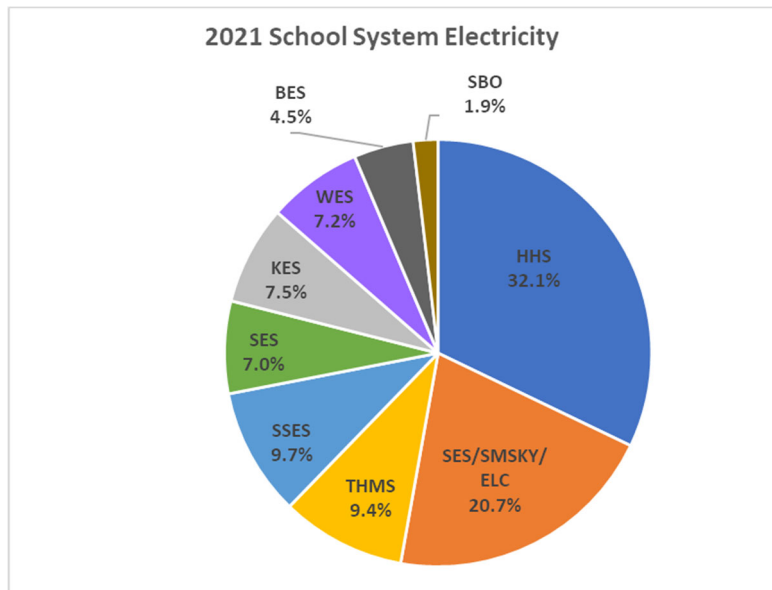


Figure 2 – Harrisonburg School Electricity Pie Chart

Community-wide electricity for Harrisonburg was provided by Brian O’Dell at HEC and is shown in Table 4 and Figure 3. The Residential sector includes all residential users while the Industrial sector includes all customers with a demand of 1000 kW or greater. JMU includes all accounts in the name of the university including the JMU Foundation, even those not located on the main campus. The Commercial sector consists of all non-Residential accounts that do not fall into any of the aforementioned categories. For future reference and data consistency, the Commercial electricity value is the sum of Rates 206, 314 and 315 and Industrial value is the sum of Rates 525 and 405. The Municipal sector includes all HEC accounts on the Municipal rate except the Water Department electricity and Sewer Flume Station which were included under the Water & Sewer sector along with the Water Treatment, Raw Water Pumping, and Sewer Authority electricity from Dominion accounts.

The electricity data shows an overall small decrease in electricity use of 0.7% for 2021 compared to 2016. In 2021, the Commercial sector and Residential sectors both contributed approximately 31% while Industrial and JMU were each approximately 17%. Note that while Municipal electricity is the sector that the City has the most control over, it contributed only 3% of the total Community usage. Electricity usage for JMU and the residential sector both increased in 2021 compared to 2016. This increase is not due to additional cooling in the summer via heat pumps or air conditioning units as the total cooling degree days (CDD) were 1042, 1140, and 971 respectively for 2016, 2019, and 2021. CDD estimate the amount of cooling needed by comparing the average daily temperature to a setpoint of 65 °F and summing the temperature differences across the entire year.

Year	Electricity Sector					Water & Sewer (kWh)	Totals (kWh)	Grid Loss (%)	Grid Loss (kWh)
	Residential (kWh)	Commercial (kWh)	Industrial (kWh)	Municipal* (kWh)	JMU (kWh)				
2016	197,228,099	232,571,151	117,197,400	20,562,197	115,370,687	10,784,741	693,714,275	4.5%	31,217,142
2019	207,255,483	234,960,057	116,416,689	21,760,751	113,493,551	10,747,220	704,633,751	5.1%	35,936,321
2021	212,213,233	214,253,579	112,928,760	20,056,394	117,749,833	11,726,732	688,928,531	5.3%	36,513,212
% Difference (2021 to 2016)	7.6%	-7.9%	-3.6%	-2.5%	2.1%	8.7%	-0.7%	17.8%	17.0%
Sector (%) 2021	30.8%	31.1%	16.4%	2.9%	17.1%	1.7%	100%		

Table 4 – Harrisonburg Community Electricity Usage by Sector

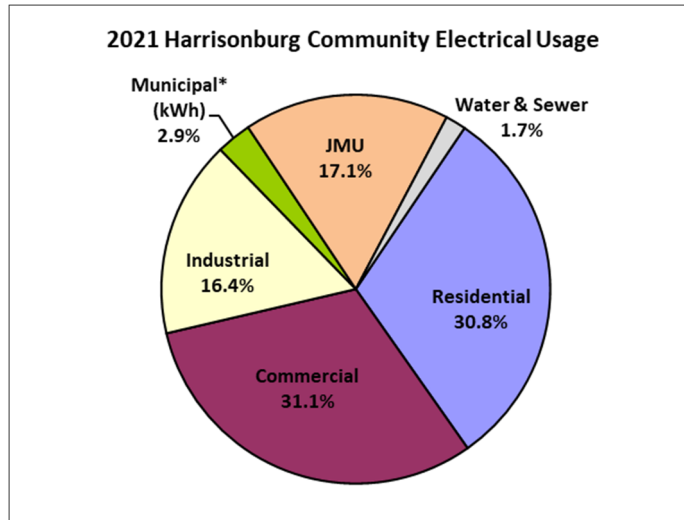


Figure 3 – Harrisonburg 2021 Community Electricity Pie Chart by Sector

Harrisonburg electricity is provided through the HEC by Dominion Energy from the generation mix they have across the regional grid. Carbon dioxide emissions factors for 2019 and 2021 were obtained from the Edison Electric Institute EEI database from the Utility Specific Residual Mix Emissions Rate column.⁴ The 2019 carbon dioxide emissions value, shown in red in Table 5, is updated from the previous report to more accurately account for energy that comes from outside of Dominion Power. The 2016 CO₂ factor remains the same in this report since the more accurate EEI database was started after this date. This EEI database does not include methane and nitrous oxide emissions factors or grid losses so the EPA eGrid³ values for the Southeast Region Virginia Carolina (SRVC) regional electricity grid were used - 2020 data were used as the 2021 data are not yet published. These differences are expected to be very small. These parameters are summarized in Table 5 and are the inputs for the ClearPath *Electricity Factor Sets*. More details from the regional grid emissions are provided in Appendix 2 noting that the carbon dioxide factors are somewhat different for Dominion Energy of Virginia compared to the entire SRVC region. The Transmission and Distribution (T&D) grid loss which is electricity lost due to resistance and inefficiencies between the power plant and the final electricity use, is included in both the Municipal and Community-level assessments based on the total electricity usage for each case.

Chemical	Electricity Emission Factors (lb/MWh)		
	2016	2019	2021
CO ₂	745 ⁵	751 ⁴	693 ⁴
CH ₄	0.067	0.058	0.050 ³
N ₂ O	0.011	0.008	0.007 ³
Grid Loss (%)	4.5	5.1 ³	5.3 ³

³Most recent EPA eGrid data (2020)

⁴EEI Database, Edison Electric Institute

⁵Dominion Energy 2019 Sustainability and Corporate Responsibility Report

Table 5 –Emissions Factors from Dominion Energy and EPA eGrid (SRVC) database

Table 6 shows the fuel mix for delivered Dominion Power Virginia Electricity⁴. The 2019 data was reported a bit differently so the fuel source percentages are lower since the fuel mix for Purchased Electricity is not detailed. Coal is generally being replaced by natural gas in recent years due to higher supply and local costs. In 2020, electricity produced from coal in the US had an average emissions factor of 2230 lb CO₂/MWh compared to 910 lb CO₂/MWh for natural gas.⁶ The emissions values in table 5 and 6 are decreasing and less than both of these fossil fuels due to the lower carbon emissions of nuclear and renewable fuel sources. Note that these emissions factors are only for the generation and use stages of the life cycle of electricity and do not account for upstream (mining, processing and fuel transportation) or downstream (waste disposal) emissions.

Year	2019	2020	2021
Total Electricity Delivered (MWh)	86,474,382	83,282,826	90,013,155
Utility Specific Residual Mix Emissions Rate (lbs/MWh)	751	712	693
Coal	7.9%	19.3%	8.8%
Natural Gas	42.3%	47.8%	49.2%
Nuclear	30.5%	22.2%	32.4%
Petroleum	0.1%	0.0%	0.1%
Biomass/Biogas	1.1%	0.0%	0.9%
Geothermal	0.0%	0.0%	0.0%
Hydroelectric	0.8%	1.9%	0.9%
Solar	0.1%	0.0%	0.5%
Wind	0.0%	0.0%	0.0%
Other		8.8%	7.2%
Purchased Power	17.2%		
	100.0%	100.0%	100.0%

Table 6 – Electricity Fuel Mix from delivered electricity from Dominion Power Virginia⁴

3b. Natural Gas

Natural gas data came from a City spreadsheet compiled from Usage History graphs provided in gas company account bills and a *City Public Schools Utilities* spreadsheet. The data is summarized in Table 7. Figure 4 shows a breakdown of the natural gas usage for 2021. The school data was provided in units of hundred cubic feet (ccf) of natural gas and converted to therms using a gas utility bill conversion factor of 1.0639 therms/ccf. Overall, the Municipal natural gas usage decreased by more than 13% for 2021 compared to the 2016 baseline. Usage is down in all subcategories. Schools dominate natural gas usage at approximately 60% in 2021 with the Department of Parks and Recreation following at approximately 20%, the Fire Department at approximately 9%, and the rest of the categories all less than 5%.

Building & Address	Meter #	2016		2019		2021		Difference 2021 - 2016 (%)
		Therms		Therms	% of Total	Therms	% of Total	
Schools - Smithland Elementary & Skyline Middle School (SMSKY)		46,896		58,701	15.5%	56,937		15.7%
Schools - Stone Spring Elementary School (SSES)		38,457		42,151	11.2%	45,501		12.5%
Schools - Thomas Harrison Middle School (TMHS)		80,111		34,565	9.2%	27,081		7.5%
Schools - Spotswood Elementary School (SES)		27,686		32,140	8.5%	30,009		8.3%
Schools - Keister Elementary School (KES)		24,105		29,830	7.9%	30,398		8.4%
Schools - Waterman Elementary School (WES)		21,044		21,728	5.8%	20,477		5.6%
Schools - Maintenance Building		4,858		5,563	1.5%	4,981		1.4%
Schools - School Board Office (SBO)		1,687		1,485	0.4%	1,288		0.4%
Schools - Harrisonburg High School (HHS)		0		0	0.0%	0		0.0%
Schools - Bluestone Elementary School (BES)		0		0	0.0%	0		0.0%
Schools - Elon Rhodes Early Learning Center (ELC)		0		0	0.0%	28		0.0%
Schools - High School Stadium		0	244,843	0	226,163	0	216,700	0.0%
Parks & Rec - Westover Pool - 305 S. Dogwood Dr	901118	48,620		35,058	9.3%	40,824		11.3%
Parks & Rec - Lucy Simms - 620 Simms Ave	M4700071	27,996		26,268	7.0%	22,263		6.1%
Parks & Rec - Community Activities Center - 305 S. Dogwood Dr	9013433	6,808		5,982	1.6%	7,648		2.1%
Parks & Rec - Golf Course Maintenance 1583 W. Market St B	6112198	3,857	87,281	3,298	70,606	2,258	72,993	0.6%
Fire Department - Public Safety Building - 101 N. Main St.	8461631	28,581		32,459	8.6%	25,757		7.1%
Fire Department Station #1 80 Maryland Ave	M8600409	1,895		4,613	1.2%	4,540		1.3%
Fire Department Station #1 Annex 90 Maryland Ave	U766302	1,048	31,524	1,104	38,176	1,098	31,395	0.3%
Transportation - Central Garage - 473 E. Washington St	13600365	24,909		15,097	4.0%	15,405		4.2%
Transportation - Administration Building - 475 E. Washington St	10600339	269	25,178	282	15,379	251	15,656	0.1%
Public Works - City Shops/Traffic Signal/Eng - 320 Mosby Rd zone 3	6074588	4,745		4,899	1.3%	4,306		1.2%
Public Works - Central Stores Warehouse - 2111 Beery Rd	M6600026	2,973		3,833	1.0%	3,405		0.9%
Public Works - City Shops/Traffic Signal/Eng - 320 Mosby Rd zone 4	97800115	3,168		2,779	0.7%	3,218		0.9%
Public Works - City Shops/Traffic Signal/Eng - 320 Mosby Rd zone 1	R171893	3,821		2,451	0.6%	2,177		0.6%
Public Works - City Shops/Traffic Signal/Eng - 320 Mosby Rd zone 2	M7400649	1,841		1,624	0.4%	1,313		0.4%
Public Works - City Shops/Traffic Signal/Eng - 320 Mosby Rd zone 5	9277707	939	17,487	744	16,330	919	15,338	0.3%
General Properties - City Hall - 409 S. Main St	M7900196	4,582	4,582	4,458	4,458	4,234	4,234	1.2%
Water Department 2155 Beery Rd	9015735	3,946	3,946	3,482	3,482	3,449	3,449	1.0%
Tourism - Hardesty Higgins House - 212 S. Main St	M4490516	3,598	3,598	2,914	2,914	2,832	2,832	0.8%
Harrisonburg Water Pump House 1790 Reservoir St	3345924	207	207	113	113	107	107	0.0%
Totals		418,646	418,646	377,621	377,621	362,704	362,704	100%

Table 7 – Harrisonburg Municipal Natural Gas Usage

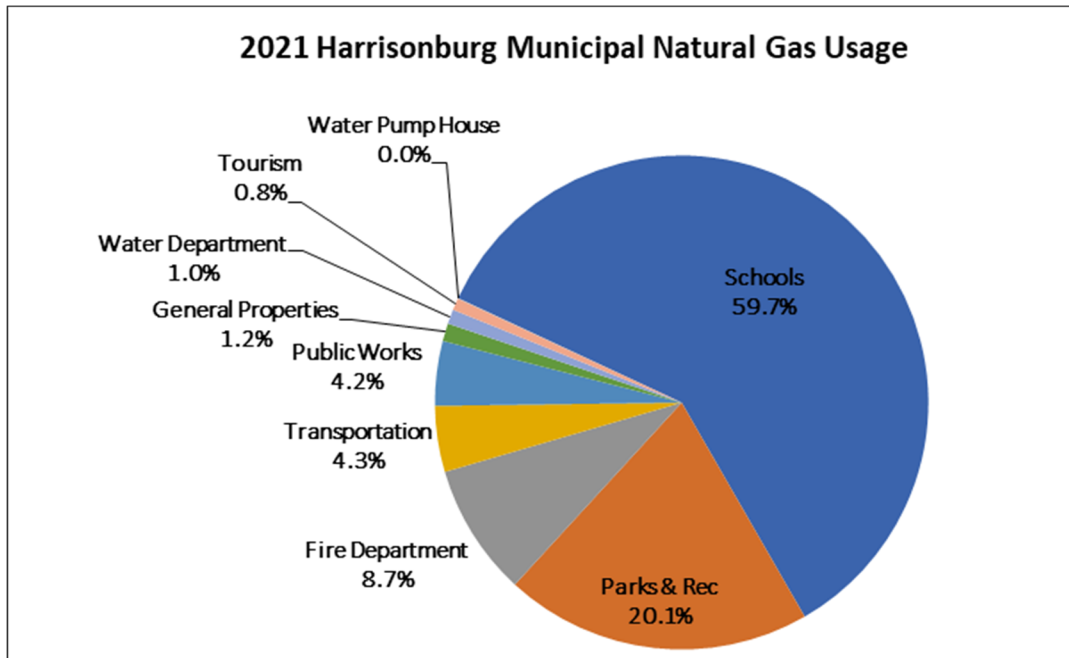


Figure 4 – Harrisonburg Municipal Natural Gas Usage 2021

Community-level natural gas usage for Harrisonburg was provided by NiSource Inc., the utility parent company of Columbia Gas of Virginia, which supplies natural gas to the City. The data provided is delineated by the City of Harrisonburg tax district.

The Community-wide natural gas data is summarized in Table 8 and Figure 5. It shows an overall increase in natural gas use from 2021 compared to 2016 of 1.2%. In 2021 the Commercial sectors was the largest at 37.7% and it includes the municipal natural gas usage detailed above, which was only 1.8% of the total Community-wide usage. This increase is not due to additional winter heating as the total heating degree days (HDD) were 4922, 4746, and 4727 respectively for 2016, 2019, and 2021. HDD estimate the amount of heating needed by comparing the average daily temperature to a setpoint of 65 °F and summing the temperature differences across the entire year.

Year	Residential (therms)	Commercial (therms)	JMU (therms)	Industrial (therms)	Totals (therms)
2016	1,733,830	6,379,270	7,837,770	4,531,220	20,482,090
2019	1,944,600	8,056,610	6,873,850	4,597,840	21,472,900
2021	1,910,455	7,818,585	5,923,260	5,077,554	20,729,854
Sector (%)	9.2%	37.7%	28.6%	24.5%	100%
Baseline Difference	10.2%	22.6%	-24.4%	12.1%	1.2%

Table 8 – Harrisonburg Community Natural Gas Usage

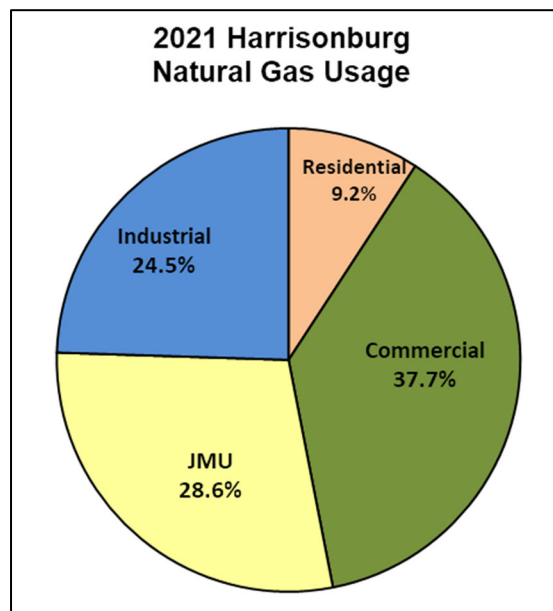


Figure 5 – Harrisonburg Community Natural Gas Usage by Sector

3c. Natural Gas Leakage

Methane emissions associated with natural gas leakage due to upstream mining, processing, and distribution are included in both the Municipal or Community-wide assessment in the ClearPath software under the *Process and Fugitive Emissions* main tab and *Fugitive Emissions From Natural Gas Distribution* subcategory. The source of GHGs is growing in the public’s awareness in recent years. The total direct municipal natural gas consumption above was used along with the indirect natural gas estimates back-calculated from utility electricity production and the fuel mix. From Dominion data in Table 6, the input fuel % for natural gas used for electricity was 35.4%, 41.8% and 40.5% in 2016, 2019,

and 2021, respectively. Leakage was assumed at 4% for municipal gas distribution and 2% for utility natural gas use for electricity production based on a number of recent references.⁷⁻⁹ Several other assumptions had to be made for these estimates including the density of natural gas at 0.713 kg/m³, energy density of 1.037 MMBtu/MCF, and a composition of 99% methane in natural gas which is on the high end of typical gas sources but more accurate for this analysis since the other contaminants in natural gas are often hydrocarbons which also release carbon dioxide upon combustion.¹⁰⁻¹¹

3d. Fuel Oil

Municipal use of Fuel Oil was reported for several of the City schools for heating and is detailed in Table 9. These values came from the Public School Utilities spreadsheet and Fiscal Year data was combined to get Calendar Year values. Other municipal uses of fuel oil were considered minimal and not assessed in this report.

Location	Fuel Oil Usage (gallons)			Difference
	2016	2019	2021	2019 – 2016 (%)
Harrisonburg High School (HHS)	49,462	54,222	62,911	9.6
Smithland Elementary & Skyline Middle School (SMSKY)	79	0	0	-100

Table 9 – Harrisonburg Municipal Fuel Oil Usage

Community-wide use of Fuel Oil for heating is difficult to measure directly and accurately since this fuel is purchased directly from various commercial suppliers by individual residents and business owners. However, the use of heating oil is too large to omit from this analysis so an estimate was used. Use of propane and wood for heating were omitted as the census data shows much lower use at 227 and 100 households, respectively, out of more than 16,700 households in the City. Residential fuel oil use was estimated since consumption averages are reasonable for a large sample of households. This analysis does not include Commercial and Industrial fuel oil use since good estimates were not available for these sectors, which are much more variable than residential housing. The 2020 Census database estimates 5.6% of total Harrisonburg households using fuel oil for heating as shown in the table 10.¹² The 2021 Census data was not yet available at the time of this analysis. The Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS) in 2015 estimates fuel oil/household energy use for the South Atlantic region, which is representative for Harrisonburg.¹³ The same values were used for all years since the RECS survey is only done every 5 years. Using a conversion factor of 139,000 BTU per gallon for fuel oil provided a conversion to the average gallons/household of fuel oil for ClearPath.

Year	Total Households	Households Heating w/ Fuel Oil ¹¹	Average Annual Fuel Oil/Household ¹² (Million BTU)	Average Annual Fuel Oil/Household (gallons)	Total Fuel Use (gallons)
2016	16,626	1,530	47.6	342	523,000
2019	16,723	1,121	47.6	342	383,000
2021	16,751	938	47.6	342	320,796

Table 10 – Harrisonburg Community Fuel Oil Usage Estimates

3e. Vehicle Transportation and Equipment Fuels

Municipal fuel use (diesel and gasoline) was compiled from the Harrisonburg *Equipment Gallon, Equipment Class* report (EGEC) and a Fuel Summary reports. A summary and graph of this data is shown in Table 11 and Figure 6. The detailed analysis tables are provided in a supplemental appendix rather than this report given the large amount of data. The EGEC report details the Equipment number by class with the total amount of fuel gallons used for each vehicle. The fuel type column lists the primary type of fuel assigned, but could have other types assigned to the vehicle. For some of the diesel fuel fleet vehicles, diesel exhaust fluid (DEF) gallons were also reported. This fluid is added to diesel exhaust emissions to reduce nitrogen oxide (NO_x) emissions from diesel exhaust and is not considered in the GHG emissions. No biofuels were used in the municipal fleet.

Diesel transit buses are the largest fleet contributor at 33% of the GHG emissions. Gas fleet vehicles and diesel school buses also contribute significantly at approximately 20% and 13%, respectively. There are large differences in 2021 from the 2016 baseline with some categories down significantly (gas vehicles, diesel school buses, and diesel equipment), other categories higher (gas paratransit and diesel fire trucks/ambulances), and the whole fleet category has 6% lower emissions from the baseline.

Vehicle/Equipment Fuels	2016		2019		2021		2021 Count	Difference 2021 - 2016 (%)
	Gallons	%	Gallons	%	Gallons	%		
Diesel Transit Buses	177,985	31.7%	188,625	32.1%	174,600	33.1%	45	-1.9%
Gas Fleet Vehicles	121,920	21.7%	118,590	20.2%	104,625	19.8%	257	-14.2%
Diesel School Buses	89,569	15.9%	98,518	16.8%	67,379	12.8%	117	-24.8%
Diesel Fleet Trucks	60,231	10.7%	58,749	10.0%	63,864	12.1%	35	6.0%
Diesel Equipment	34,439	6.1%	37,658	6.4%	24,180	4.6%	60	-29.8%
Gas Police Vehicles	28,939	5.1%	37,597	6.4%	40,311	7.6%	46	39.3%
Gas ParaTransit Buses	21,208	3.8%	24,833	4.2%	25,270	4.8%	12	19.2%
Diesel Fire Trucks/Ambulances	23,728	4.2%	19,490	3.3%	20,526	3.9%	16	-13.5%
Gas Equipment	4,070	0.7%	3,417	0.6%	6,949	1.3%	38	70.7%
TOTALS	562,089	100%	587,477	100%	527,703	100%	626	-6.1%

Table 11 – Harrisonburg Municipal Fleet Vehicle/Equipment Fuel Usage

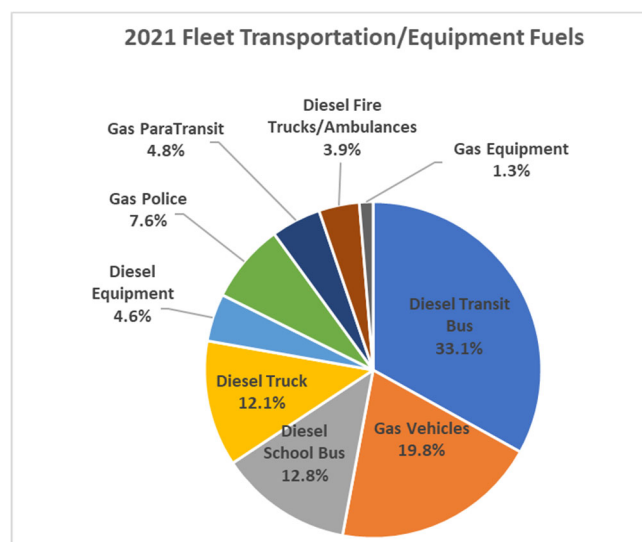


Figure 6 – Harrisonburg Vehicle/Equipment Fuel Usage

For Community-wide fuel use, the transportation sector was analyzed using Vehicle Miles Travelled (VMT) data from the 2016, 2019, and 2021 Virginia Department of Transportation (VDOT) report 1220.¹⁴ Daily VMT was measured through VDOT traffic counts and were multiplied by 365 days to determine the Annual VMT. Table 12 provides a summary of the VMT by Road Type. 2021 VMT was 6.3% lower than the 2016 baseline. Miles driven on the I-81 through Harrisonburg are the largest category at 40% as shown in Figure 7, with Primary roads at 32%, and Secondary Roads at 27%. VMT values were converted to emissions using the default US National Vehicle Fuel economy and emissions factor sets provided in ClearPath. VDOT federal vehicle class info from Report 1220 was again used for the percentage of the vehicle types shown in Table 13. This data does not distinguish fuel type for passenger and light trucks which were all assigned gasoline while diesel was assumed for all heavy trucks. More vehicle categories were available in ClearPath as seen in Appendix 3, but the additional detail was not considered to make enough differences for the additional analysis. Fuel economies (gallons/mile) and GHG emissions (grams CH₄/mile and grams N₂O/mile) by vehicle types provided the conversion from VMT to gallons of fuel and GHG emissions.

Year	DVMT By Road Type (miles)				Annual	Difference
	Secondary	Primary	Interstate	Total	VMT (miles)	(%)
2016	255,020	304,428	358,494	917,942	335,048,830	baseline
2019	264,760	302,838	382,063	949,661	346,626,265	3.5%
2021	235,384	278,385	346,136	859,906	313,865,545	-6.3%

Table 12 – VDOT VMT data for Harrisonburg in 2016, 2019, and 2021.

Sub Totals	Fuel	VMT (%)	Federal Vehicle Class	#	Clear Path Label
273,787,755	Gasoline	0.2%	Motorcycles	01	Motorcycles
		70.2%	Passenger Cars	02	Passenger Cars
		16.8%	Two Axle, 4 Tire Single Unit Vehicles	03	Light Trucks
		87.2%	Gasoline Subtotal		
40,077,790	Diesel	0.5%	Busses	04	Heavy Trucks
		1.0%	Two Axle, 6 Tire Single Unit Trucks	05	
		0.7%	Three Axle Single Unit Trucks	06	
		0.1%	Four or More Axle Single Unit Trucks	07	
		0.5%	Four Axle or Fewer Single Trailers	08	
		9.1%	Five Axle Single Trailers	09	
		0.1%	Six or More Axle Single Trailers	10	
		0.4%	Five Axle or Fewer Multi-Trailers	11	
		0.3%	Six Axle Multi-Trailers	12	
		0.0%	Seven or More Axle Multi-Trailers	13	
		12.8%	Diesel Subtotal		
313,865,545		100.0%	Total Transportation		

Table 13 – VDOT Vehicle Percentages in 2021.

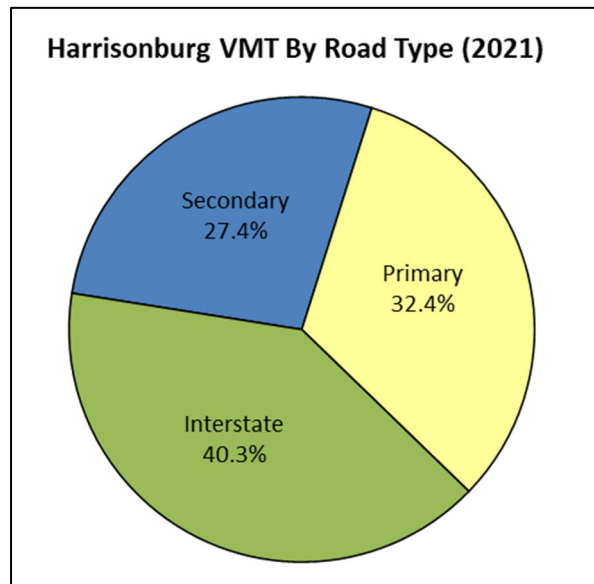


Figure 7 – Harrisonburg Vehicle Miles Traveled By Road Type (2021)

3f. Waste Disposal

Harrisonburg City Community solid waste is sent to the Rockingham County Landfill. Waste tonnage data was obtained from the Area MSW Annual Data spreadsheet provided by Harsit Patel, Support Services Manager in the City of Harrisonburg Department of Public Works. The data is summarized in Table 14 for 2016, 2019, and 2021. Even though the solid waste is broken down by several categories, the Mixed Solid Waste (MSW) default (100%) method in ClearPath based on the EPA WARM v14 model was used since these waste data categories do not match up well with the detailed categories in the ClearPath Waste Factor sets. The default waste percentages are based on the US municipal averages since specific waste percentages were not available for the City of Harrisonburg municipal waste. These differences are important in the interpretation of the landfill methane in the 20-yr GHG totals. Municipal solid waste was not analyzed due to the lack of detailed waste data at the Municipal level.

Harrisonburg City Waste	Municipal Solid Waste (residential refuse)	Commerical Refuse ¹	Non-chargeable on report	Concrete, Dirt, Rock	Construction/ Demolition/ Wood Debris	Industrial Waste ²	Vegetative/ Yard Waste ³	Unsorted Rubbish	Sludge	Total
2016	2,732	7,249	48	510	4,224	48	1,002	126	22	15,961
2019	11,584	18,218	419	64	3,954	126	465	59	434	35,323
2021	10,623	15,079	374	8	2,943	237	863	29	8	30,164

¹Includes agriculture and cows
²Includes flyash
³Includes commercial brush, re-route brush, xmas trees
⁴The accuracy of the waste tonnage reported is dependent on the Rockingham County Landfill customers, including private haulers, providing the attendant with the correct source of their refuse.

Table 14 – Harrisonburg Waste Summary

Annual rainfall in Harrisonburg in the 35 - 40 inches range which led to selecting “Moderate” moisture for the ClearPath Landfill Model. Landfill gas is flared from this landfill so “Typical” was chosen for Landfill Collection Scenario in the model.

The ClearPath waste calculator has recently been updated to better align with advancements to the EPA Waste Reduction Model (WARM). This calculation method estimates all future methane emissions from the fraction of the organic (carbon-based) mass sent to landfill and attributes them all to the current Inventory Year. The calculation uses a Waste Characterization Factor Set and methane emission factors from EPA's WARM model, version 14, with equation 1 to estimate total methane landfill emissions.¹⁵ This calculator differs from WARM slightly by using a simplified calculation for oxidation of methane passing through soil on top of the landfill. WARM uses an oxidation factor of 10 - 30%, depending on the stage of the life of the landfill. For simplicity, this calculator uses a constant 10% oxidation rate, resulting in a slightly higher emissions estimate. Each material in the Waste Factor set produces a certain amount of methane emissions per ton of waste material over its lifetime in the landfill.

$$\text{Methane Emissions} = \text{Waste Tonnage} \times (1 - X_{ox}) \times \sum(\%_m \times EF_m \times (1 - LFG_m)) \quad (\text{Equation 1})$$

where X_{ox} is Percent Oxidation Rate (0.1),
 $\%_m$ is the percent of each material type, m, in the landfill waste stream,
 EF_m is the lifetime methane emissions factor for each material type, m, and
 LFG is the lifetime landfill gas capture percentage for each material type, m

3g. Biogas from Waste Water Treatment

Biogas is generated by various processes in the Harrisonburg Rockingham Regional Sewer Authority (HRRSA). The biogas has a composition of approximately 67% methane (CH₄) and 33% carbon dioxide (CO₂). Prior to 2019, biogas was combusted (flared) in a waste gas burner to convert the methane which is a much stronger GHG than carbon dioxide. This combustion process is estimated to be 98% efficient at methane conversion. Starting in 2019, some of the biogas was used to heat the HRRSA biosolids dryer and anaerobic digesters. The volumes of biogas are provided in Table 15. Note that data for 2016 and 2019 were for the fiscal year, but 2021 data was obtained for the calendar year to match most of the other data in this report. The City of Harrisonburg contributes approximately half of the water to the waste water treatment facility (WWTF) so the biogas was attributed to the City based on the percentage in both the Municipal and Community inventories. This analysis estimates emissions from the combustion of Digester Gas according to the ICLEI US Community Protocol Appendix F: *Wastewater and Water Emission Activities and Sources methods WW.1.a* for CH₄, *WW.2.a* for N₂O and *WW.3* for biogenic CO₂.

Year	Biogas Flared (cubic feet)	Biogas Use in Biosolids Dryer (cubic feet)	% Attributed to Harrisonburg City
2016	67,673,385	0	53%
2019	67,673,385	12,121,322	53%
2021	25,525,000	86,368,196	56.4%

Table 15 – Harrisonburg Rockingham Regional Sewer Authority (HRRSA) biogas data

3h. Recycling

Community-wide recycling data was obtained from the Harrisonburg Public Works Department Year-to-Date Solid Waste Report and detailed in Table 16. This particular recycling data was not available for 2016. Note that ClearPath does not give emissions credits for recycled materials as this methodology is not considered appropriate by all GHG emissions methods. However, these estimates are useful metrics as recycling is an important community activity.

Therefore, the EPA WARM model (v.15) was used to estimate avoided emissions due to recycling.¹⁶ The recycling amounts for the various categories in Table 16 were multiplied by the associated WARM emissions savings and summed. The emissions savings are across the life cycle due to the recycled materials being used instead of virgin materials. These absolute recycling emissions can be considered as unofficial offsets to the Community emissions.

Category	Waste Amount (tons)		Savings (tons CO ₂ /ton waste)	WARM v15 Categories
	2019	2021		
Cardboard	188.7	285	3.14	Corrugated containers
Glass	99.3	103.3	0.28	Glass
Tin/Scrap	95.7	49.9	4.39	Mixed Metals
Mixed Paper	78.2	82.39	3.55	Mixed Paper
Plastic 1	19.8	26	1.04	PET
Plastic 2	9.6	11.7	0.76	HDPE
Plastic Bags	7.6	8.8	0.00	LDPE
Aluminum	3.0	10.3	9.13	Aluminum Cans
Totals	502	577		
Carbon Emissions (mt CO₂)	1,245	1,420	EPA WARM v15 estimate	

Table 16 – Harrisonburg Solid Waste Management Recycling Data

4. ANALYSIS RESULTS

The ICLEI ClearPath online software was used to analyze the data detailed in the previous sections to provide estimates of the GHG emissions for Harrisonburg in 2021 and compare to previous years including the 2016 (baseline year). All greenhouse gas emissions are normalized to carbon dioxide (CO₂) using the IPCC 5th report global warming potentials (GWPs), which account for the impact of the specific chemical emissions relative to this standard reference. Total GHG emissions are therefore reported in mass units of CO₂ equivalent (CO_{2e}) in metric tons, which are 1.1 times heavier than US (short) tons. Analyses are shown for both the 100-yr and 20-yr GWP values.

4a. Municipal Greenhouse Gas Emissions

Total Municipal GHGs calculated by ClearPath using the inventory data, assumptions, and factor sets detailed above are shown in Tables 17 and 18 at the broad sector and fuel source level. Values highlighted in red in the 100-yr GWP result tables are minor updates to the analysis for 2016/2019 due to inclusion of methane leakage directly in the ClearPath analysis, a revision to the electrical grid loss in 2019, and a double-counting error. The small differences in the Sector and Source table totals are due to rounding of subtotals in the calculations. Total Municipal GHG emissions were 5.2% less in 2021 than in 2016 for the 100-yr analysis. The main difference for the 20-yr analysis are Natural Gas leakages values which roughly triple in the 20-yr analysis due to the higher GWP over this time frame. Municipal emissions are dominated by the Buildings/Facilities sector, which are 32% and 39%, respectively, for the 20-yr and 100-yr analysis. Electricity is the dominant municipal source of GHGs contributing 42% and 51% of the emissions, respectively, for the 20-yr and 100-yr analysis.

100-yr GWP

Sector	ClearPath 2016 (mtons)	ClearPath 2019 (mtons)	ClearPath 2021 (mtons)	2021 Sector (%)	2021 - 2016 Baseline Difference (%)
Buildings/Facilities	8,698	8,974	7,980	38.7%	-8.3%
Water & Sewer	3,920	3,932	3,812	18.5%	-2.8%
Vehicle Fleet	3,473	3,590	3,129	15.2%	-9.9%
Natural Gas (Methane) Leakage	2,130	2,306	2,194	10.7%	3.0%
Transit Fleet	2,003	2,143	2,004	9.7%	0.0%
Street/Traffic Lights	1,029	1,041	947	4.6%	-8.0%
Electric Grid Loss	479	567	531	2.6%	10.9%
Totals	21,732	22,553	20,597	100.0%	-5.2%

20-yr GWP

Sector	ClearPath 2016 (mtons)	ClearPath 2019 (mtons)	ClearPath 2021 (mtons)	2021 Sector (%)	2021 - 2016 Baseline Difference (%)
Buildings/Facilities	8745	9017	8018	31.6%	-8.3%
Natural Gas (Methane) Leakage	6467	6998	6661	26.3%	3.0%
Water & Sewer	4452	4463	4038	15.9%	-9.3%
Vehicle Fleet	3473	3590	3129	12.4%	-9.9%
Transit Fleet	2003	2143	2004	7.9%	0.0%
Street/Traffic Lights	1034	1045	950	3.7%	-8.1%
Electric Grid Loss	482	570	534	2.1%	10.8%
Totals	26,656	27,826	25,334	100.0%	-5.0%

Table 17 – Harrisonburg Municipal ClearPath GHG Emissions by Sector (100-yr and 20-yr GWP)

100-yr GWP

Emissions Source	ClearPath 2016 (mtons)	ClearPath 2019 (mtons)	ClearPath 2021 (mtons)	2021 Sector (%)	2021 - 2016 Baseline Difference (%)
Electricity	11,141	11,697	10,570	51.3%	-5.1%
Diesel	3,930	4,115	3,579	17.4%	-8.9%
Natural Gas	4,356	4,314	4,142	20.1%	-4.9%
Gasoline	1,546	1,619	1,555	7.6%	0.6%
Fuel Oil	509	557	646	3.1%	27.0%
Biogas	252	253	109	0.5%	-57.0%
Totals	21,736	22,556	20,602	100.0%	-5.2%

20-yr GWP

Emissions Source	ClearPath 2016 (mtons)	ClearPath 2019 (mtons)	ClearPath 2021 (mtons)	2021 Sector (%)	2021 - 2016 Baseline Difference (%)
Electricity	11,198	11,748	10,613	41.9%	-5.2%
Natural Gas	8,705	9,018	8,620	34.0%	-1.0%
Diesel	3,930	4,115	3,579	14.1%	-8.9%
Gasoline	1,546	1,619	1,555	6.1%	0.6%
Fuel Oil	513	562	652	2.6%	27.1%
Biogas	766	768	320	1.3%	-58.2%
Totals	26,659	27,830	25,339	100.0%	-5.0%

Table 18 – Harrisonburg Municipal ClearPath GHG Emissions by Source (100-yr and 20-yr GWP)

Total Municipal GHGs in the 100-yr analysis are plotted in Figures 8 and 9 for the sectors and sources. The 20-yr plots are not shown here as they are primarily different only for natural gas leakage. It is clear from these plots that Buildings and Electricity are the biggest contributors and opportunities for future GHG reductions. It is important to remember that reductions to electricity use will also lead to less natural gas leakage and GHG emissions due to the use of natural gas by Dominion to generate almost 50% of the utility electricity as seen in Table 6.

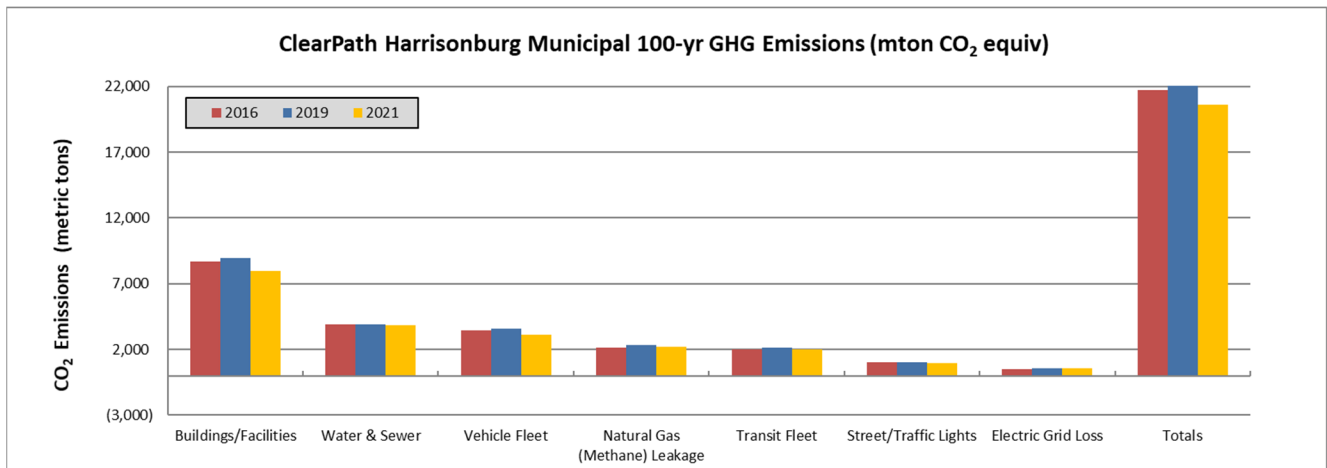


Figure 8 – Harrisonburg Municipal 100-yr GHGs by Sector

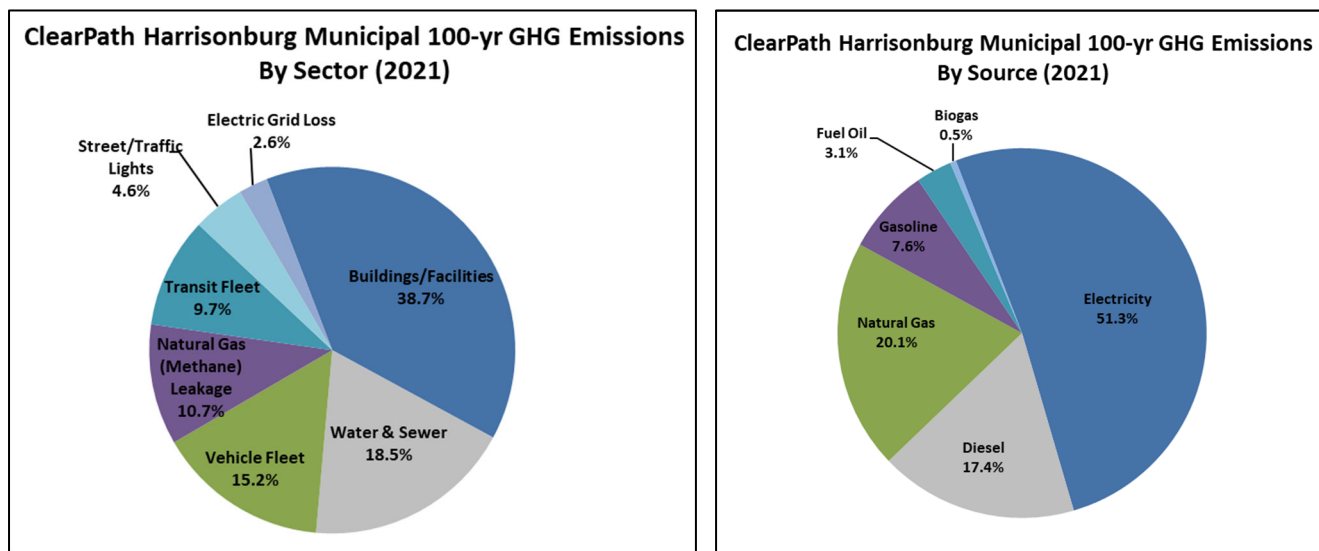


Figure 9 – Harrisonburg Municipal 100-yr GHG emissions by Sector and Source 2021

Table 19 provides the 100-yr GHG emissions results at a more detailed level for the category, sector and fuel source. School electricity is the largest emissions contributor at 17.5% followed by Sewer Authority electricity, diesel for City Transit Buses, and natural gas leakage from utility fuel consumption.

Category	Sector	Fuel Source	CO _{2e} (mton)			2021	Difference
			2016	2019	2021	Category (%)	2021 vs 2016 (%)
SCHOOLS	Buildings/Facilities	Electricity	3,865	4,308	3,613	17.5%	-6.5%
SEWER AUTHORITY	Water & Sewer	Electricity	2,469	2,501	2,511	12.2%	1.7%
CITY TRANSIT BUSES	Transit Fleet	Diesel	1,817	1,926	1,783	8.7%	-1.9%
NATURAL GAS (METHANE) LEAKAGE	Utility	Natural Gas	1,190	1,458	1,380	6.7%	15.9%
WATER DEPT	Water & Sewer	Electricity	1,199	1,179	1,192	5.8%	-0.5%
SCHOOLS	Buildings/Facilities	Natural Gas	1,302	1,203	1,153	5.6%	-11.5%
TRAFFIC & STREET LIGHTS	Street/Traffic Lights	Electricity	1,029	1,041	947	4.6%	-8.0%
FLEET VEHICLES	Vehicle Fleet	Gasoline	1,106	1,071	919	4.5%	-17.0%
NATURAL GAS (METHANE) LEAKAGE	Municipality	Natural Gas	941	848	815	4.0%	-13.3%
SCHOOL BUSES	Vehicle Fleet	Diesel	914	1,006	688	3.3%	-24.8%
DIESEL TRUCKS	Vehicle Fleet	Diesel	847	799	652	3.2%	-23.0%
SCHOOLS	Buildings/Facilities	Fuel Oil	509	557	646	3.1%	27.0%
ELECTRICAL GRID LOSS	Buildings/Facilities	Electricity	480	568	532	2.6%	10.9%
FIRE DEPT	Buildings/Facilities	Electricity	551	609	531	2.6%	-3.6%
PARKS & REC DEPT	Buildings/Facilities	Electricity	602	607	480	2.3%	-20.3%
PARKS & REC DEPT	Buildings/Facilities	Natural Gas	464	376	388	1.9%	-16.4%
POLICE CARS	Vehicle Fleet	Gasoline	254	330	354	1.7%	39.3%
COMMUNITY DEVELOPMENT	Buildings/Facilities	Electricity	269	264	249	1.2%	-7.3%
DIESEL EQUIPMENT	Vehicle Fleet	Diesel	352	384	247	1.2%	-29.8%
TRANSPORTATION DEPT	Buildings/Facilities	Electricity	370	305	234	1.1%	-36.7%
PARATRANSIT BUSES	Transit Fleet	Gasoline	186	218	222	1.1%	19.2%
DIESEL FIRE/AMBULANCE	Transit Fleet	Diesel	w/ diesel trucks		210	1.0%	
FIRE DEPT	Buildings/Facilities	Natural Gas	168	203	167	0.8%	-0.4%
PUBLIC WORKS	Buildings/Facilities	Electricity	128	74	128	0.6%	0.2%
SEWER AUTHORITY	Water & Sewer	Biogas	252	252	101	0.5%	-59.9%
TRANSPORTATION DEPT	Buildings/Facilities	Natural Gas	134	82	83	0.4%	-37.8%
PUBLIC WORKS	Buildings/Facilities	Natural Gas	93	87	82	0.4%	-12.3%
PARKING SERVICES	Buildings/Facilities	Electricity	90	3	71	0.3%	-20.5%
EMERGENCY COMM CENTER (HRECC)	Buildings/Facilities	Electricity	64	82	65	0.3%	0.5%
FLEET GASOLINE EQUIPMENT	Transit Fleet		w/ gasoline fleet		61	0.3%	
MISCELLANEOUS MUNICIPAL	Buildings/Facilities	Natural Gas			56	0.3%	
WATER DEPT	Buildings/Facilities	Natural Gas	21	19	18	0.1%	-12.6%
CENTRAL STORES	Buildings/Facilities	Electricity	22	16	11	0.1%	-48.1%
SEWER AUTHORITY	Water & Sewer	Biogas	0	1	7	0.0%	
POLICE DEPT	Buildings/Facilities	Electricity	2	140	3	0.0%	48.1%
CITY HALL	Buildings/Facilities	Natural Gas	24	24	0	0.0%	
SEWER AUTHORITY	Water & Sewer	Electricity	0.3	0.4	0	0.0%	
TOURISM	Buildings/Facilities	Natural Gas	19	15	0	0.0%	
			21,736	22,556	20,602	100.0%	-5.2%

Table 19 – Harrisonburg Municipal ClearPath Detailed 100-yr GHG Emissions by Source and Fuel

School operations (buildings and buses) have emissions from multiple fuel sources and are also 4 of the top dozen categories as seen in Table 19. The four school energy sources of electricity, natural gas, fuel oil, and diesel fuel (school buses) contribute 30% of all Municipal emissions in 2021. Therefore, to provide more insight and detail, the School sector emissions are broken down further in Table 20. In the school category, electricity accounts for the largest contribution to GHG emissions at 59% as seen in the pie chart of Figure 10. Overall, School GHG Emissions have decreased in 2021 by approximately 7% from 2016.

School Category/Detail	Sector	Fuel Source	CO2e (mton)			2021 Category (%)	Difference 2021 vs 2016 (%)
			2016	2019	2021		
Harrisonburg High School	Buildings/Facilities	Electricity	1,145	1,430	1,161	19.0%	24.9%
Smithland Elementary & Skyline Middle			797	840	747	12.2%	5.4%
Thomas Harrison Middle School			619	462	747	12.2%	-25.3%
Stone Spring Elementary School			383	438	341	5.6%	14.3%
Spotswood Elementary School			282	303	350	5.7%	7.4%
Keister Elementary School			285	290	253	4.1%	1.7%
Waterman Elementary School			279	284	271	4.4%	1.6%
Bluestone Elementary School			0	184	259	4.2%	
School Board Office			75	78	163	2.7%	4.1%
School Electricity Totals			3,865	4,308	3,613	59.2%	-6.5%
Smithland Elementary & Skyline Middle	Buildings/Facilities	Natural Gas	249	312	316	27.4%	26.7%
Stone Spring Elementary School			205	224	253	21.9%	23.5%
Keister Elementary School			128	159	169	14.6%	31.6%
Thomas Harrison Middle School			426	184	150	13.0%	-64.7%
Spotswood Elementary School			147	171	167	14.5%	13.1%
Waterman Elementary School			112	116	114	9.9%	1.6%
Maintenance Building			26	30	28	2.4%	7.0%
School Board Office			9	8	7	0.6%	-20.3%
Elon Rhodes Early Learning Center (ELC)			-	-	0	0.0%	
School Natural Gas Totals			1,302	1,203	1,153	18.9%	-11.5%
School Bus Diesel Fuel Totals	Vehicle Fleet	Diesel	914	1,006	688	11.3%	10.0%
Harrisonburg High School	Buildings/Facilities	Fuel Oil	508	557	646	56.1%	9.6%
Smithland Elementary & Skyline Middle			1	0	0	0%	
School Fuel Oil (Heating) Totals			509	557	646	10.6%	9.4%
TOTALS			6,591	7,074	6,100	100.0%	-7.4%

Table 20 –Harrisonburg School Detailed 100-yr GHG Emissions by Source and Fuel

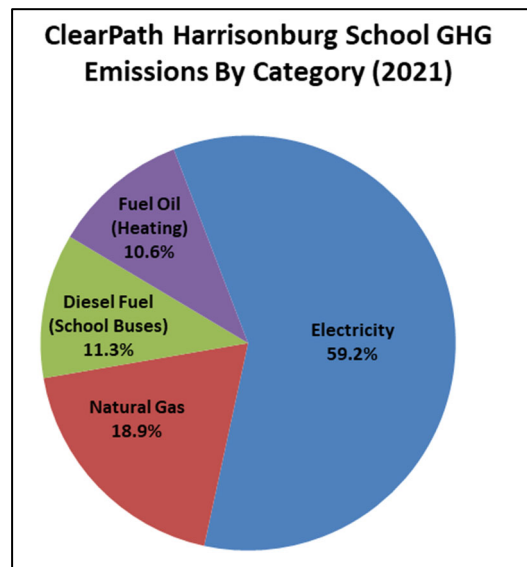


Figure 10 – Harrisonburg School-Related 100-yr GHG emissions by Category (2021)

4b. Community GHG Emissions

Community GHGs calculated by ClearPath are shown in Tables 21 and 22 and Figures 11 - 13 by sector and fuel source based on both 20-yr and 100-yr GWP values. Values shown are red in the upper 100-yr GWP table have been updated from the previous 2016/2019 analysis due to updates to the carbon emissions factors for consistency, direct inclusion of methane leakage in ClearPath, a change in the Landfill Methane Collection, and a revision to the electrical grid loss for 2019. The 20-yr GWP values in the lower table are 30% higher due to the GWP of methane which is approximately 3 times higher relative to carbon dioxide due to its shorter lifetimes in the atmosphere.

Total emissions decreased 3.4% in 2021 compared to 2016 using the 100-yr GWP values and 1.0% lower using the 20-yr values. Community emissions are dominated by the Commercial and Transportation sectors in the 100-yr analysis at around 30% of the total each. In the 20-yr analysis, Natural Gas leakage becomes the largest category. Methane leakage estimated from natural gas lines in the community and indirectly from natural gas used for electricity generation is 13% in the 100-yr analysis and 29% in the 20-yr analysis. For both analyses, the 2021 GHG totals are lower than the 2019 totals in part due to the carbon emissions factors for electricity from Dominion Power listed in Table 5.

100-yr GWP

Sector	ClearPath 2016 (mtons CO2e)	ClearPath 2019 (mtons CO2e)	ClearPath 2021 (mtons CO2e)	2016 Baseline Difference (%)	2021 Sector (%)
Commercial	200,943	206,151	184,274	-8.3%	30.3%
Transportation	179,691	182,964	169,626	-5.6%	27.9%
Residential	81,672	85,497	80,477	-1.5%	13.2%
Natural Gas Leakage	72,359	79,837	76,487	5.7%	12.6%
Industrial	63,908	64,257	62,613	-2.0%	10.3%
Solid Waste	16,914	23,072	19,703	16.5%	3.2%
Electricity Grid Loss	10,616	12,302	11,531	8.6%	1.9%
Water & Wastewater	3,920	3,932	3,813	-2.7%	0.6%
Totals	630,023	658,012	608,524	-3.4%	100.0%

20-yr GWP

Sector	ClearPath 2016 (mtons CO2e)	ClearPath 2019 (mtons CO2e)	ClearPath 2021 (mtons CO2e)	2016 Baseline Difference (%)	2021 Sector (%)
Natural Gas Leakage	219,608	242,306	232,137	5.7%	28.8%
Commercial	201,985	207,130	185,119	-8.4%	23.0%
Transportation	180,037	183,295	169,919	-5.6%	21.1%
Residential	82,107	85,896	80,833	-1.6%	10.0%
Industrial	64,136	64,457	62,788	-2.1%	7.8%
Solid Waste	51,348	70,041	59,813	16.5%	7.4%
Electricity Grid Loss	10,670	12,356	11,578	8.5%	1.4%
Water & Wastewater	4,452	4,463	4,040	-9.3%	0.5%
Totals	814,343	869,944	806,227	-1.0%	100.0%

Table 21 – Harrisonburg Community ClearPath GHG Emissions by Sector for 2 Time Horizons

100-yr GWP

Emissions Source	ClearPath 2016 (mtons)	ClearPath 2019 (mtons)	ClearPath 2021 (mtons)	Baseline Difference (%)	2021 Source (%)
Electricity	246,549	253,532	229,106	-7.1%	37.6%
Natural Gas	181,245	187,586	186,685	3.0%	30.7%
Gasoline	116,826	118,133	106,252	-9.1%	17.5%
Diesel	62,865	64,832	63,375	0.8%	10.4%
Solid Waste	16,915	23,072	19,703	16.5%	3.2%
Fuel Oil	5,374	10,609	3,296	-38.7%	0.5%
Biogas	252	253	110	0.5%	0.02%
Totals	630,027	658,016	608,528	-3.4%	100.0%

20-yr GWP

Emissions Source	ClearPath 2016 (mtons)	ClearPath 2019 (mtons)	ClearPath 2021 (mtons)	Baseline Difference (%)	2021 Source (%)
Natural Gas	328,975	350,539	342,810	4.2%	42.5%
Electricity	247,801	254,639	230,042	-7.2%	28.5%
Gasoline	117,162	118,452	106,532	-9.1%	13.2%
Diesel	62,876	64,844	63,387	0.8%	7.9%
Solid Waste	51,349	70,041	59,814	16.5%	7.4%
Fuel Oil	5,418	10,665	3,324	-38.7%	0.4%
Biogas	766	768	322	-57.9%	0.0%
Totals	814,347	869,948	806,230	-1.0%	100.0%

Table 22 – Harrisonburg Community ClearPath GHG Emissions by Source for 2 Time Horizons

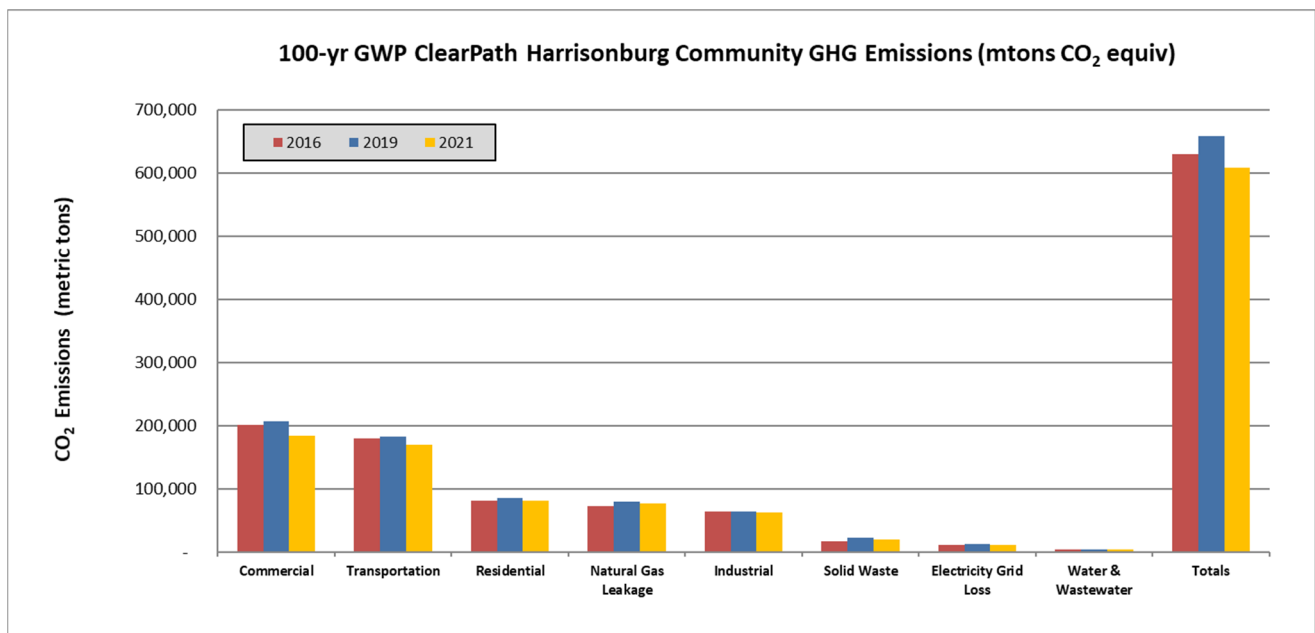


Figure 11 – Harrisonburg Community GHGs by Sector (100-yr GWP)

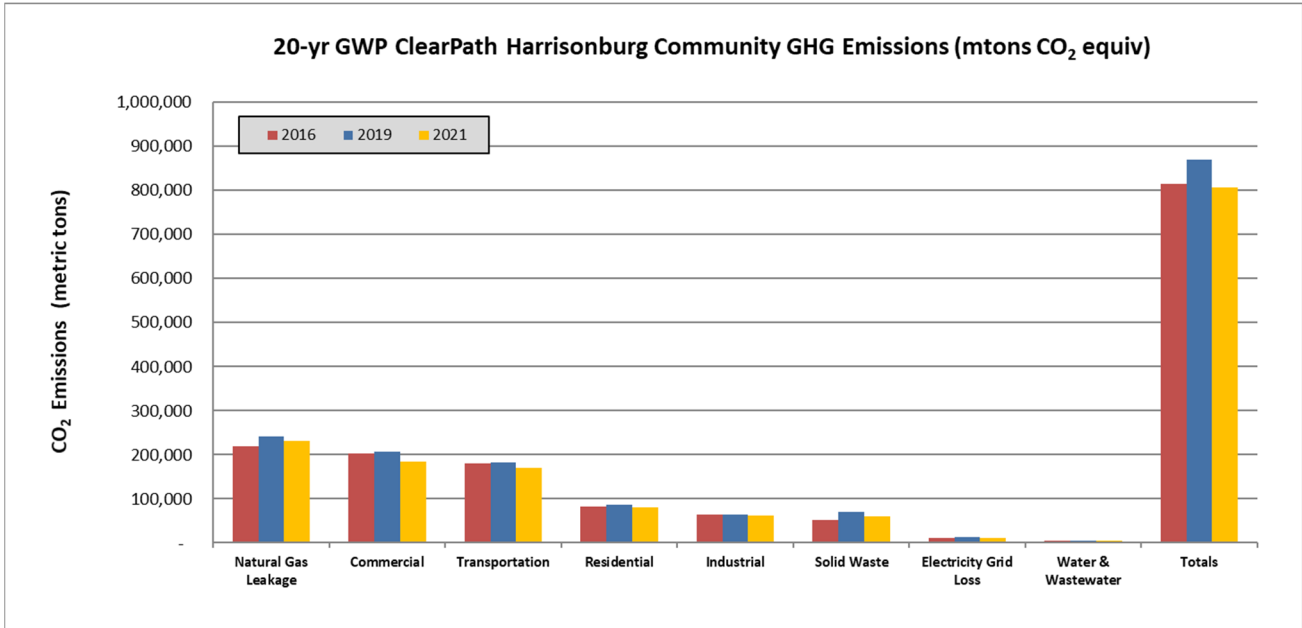


Figure 12 – Harrisonburg Community GHGs by Sector (20-yr GWP)

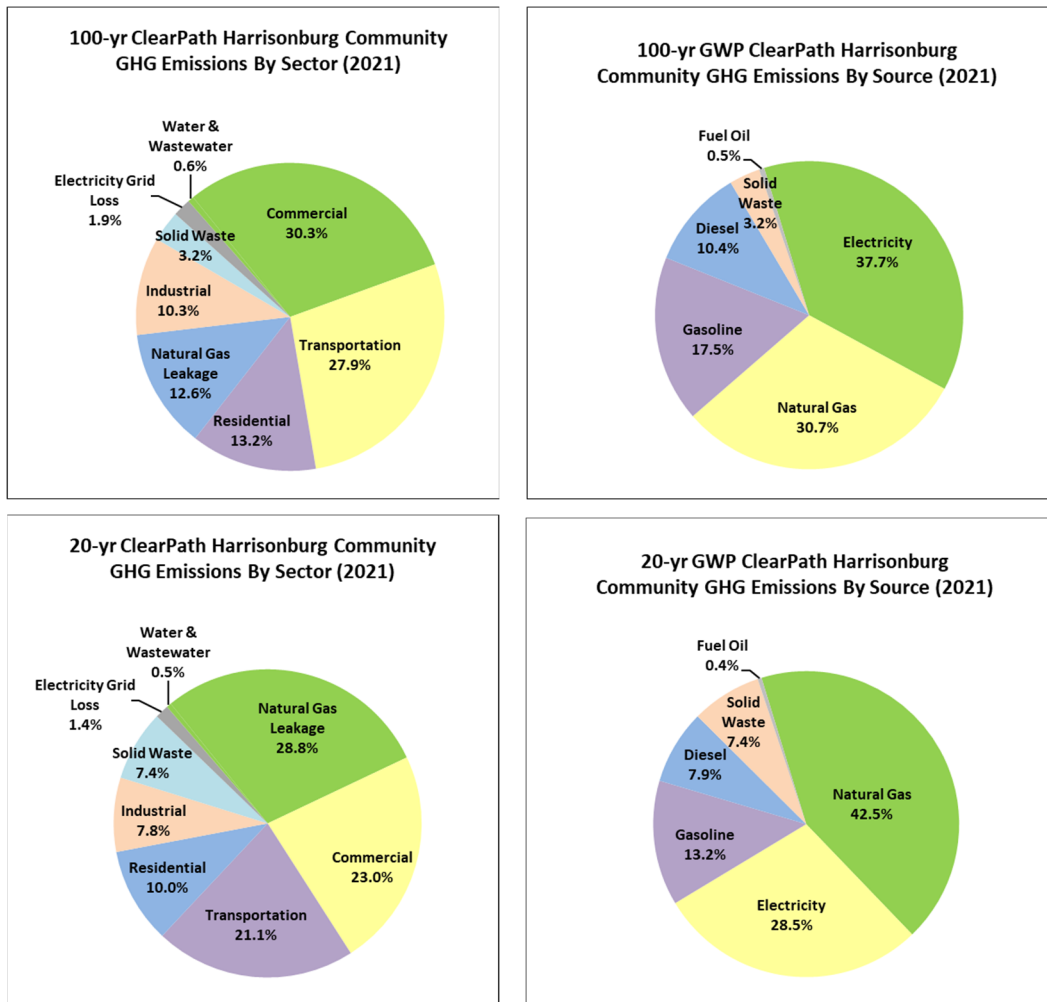


Figure 13 – Harrisonburg Community GHG emissions by Sector and Source 2021

Note that vehicle emissions are being overcounted slightly using this methodology. VMTs are the most reliable way to quantify Community level transportation miles, but the method depends on a vehicle and mile count so it does not differentiate electric from gasoline (or diesel) vehicles. Therefore, in this method the electric vehicle VMTs are included with associated carbon dioxide emissions. In reality, the carbon dioxide emissions for electric vehicles occur at the utility power plants rather than at the tailpipe since there is no combustion, just electricity use. So, a small number of VMTs from electric vehicles shown in Table 13 are double-counted since their carbon emissions are included in the electricity usage data and also in the VMT analysis. In the future, this analysis will account for these avoided EV tailpipe emissions, but the electric vehicle penetration is currently so low that the errors are currently insignificant. Gasoline hybrid vehicles are also more fuel efficient, but they are accounted for properly as their higher fuel economies and gasoline use are factored into the vehicle fuel economy estimates by year.

Year	2016	2019	2021
Hybrid Vehicles	288	530	716
Electric Vehicles	5	26	65

Table 23 - City of Harrisonburg alternative vehicle counts

4c. Recycling Carbon Emissions Savings

As mentioned above, recycling provides emissions savings since the virgin raw materials and some of the processing and transportation are not required for new products. Formally, ClearPath and most emissions protocols do not provide recycling credits for a number of technical reasons including the fact that recycling can increase simply because consumption increases. Consumption of materials other than energy and fuels is out of scope for this analysis, so it’s not appropriate to give credit for the recycling due to consumption when consumption of materials is not counted.

Recycling is an important community activity, though, so these unofficial estimates are provided outside the ClearPath analysis. The emissions savings due to recycling is approximately 0.2% of the Community total, so even though 1,520 tons of recycling is a large number, the impact on emissions savings is quite small and the recycling program should not be prioritized over the much larger emissions reductions available from conservation of energy and fuels.

5. DISCUSSION AND CONCLUSIONS

With this GHG emissions analysis complete, the next step is to continue to set and refine goals and GHG targets using a local action plan at the Municipal and Community levels to help achieve these goals. In the last few years, GHG goals to reduce the effects of climate change have become much more aggressive as the significant impacts of this problem have become clearer. Many jurisdictions and organizations are adopting the goals of reducing GHG emissions to 50% by 2030 and achieving carbon neutrality by 2050. This range of targets and goals is aggressive, but in line with recommendations by climate scientists to avoid the worst scenarios of climate change.

Local action plans will generally include a mix of the following actions for reducing GHG emissions (in order of highest cost effectiveness and feasibility): Energy conservation, Efficiency improvements, Utility carbon intensity reduction, Renewable energy generation, Renewable energy credits (RECs) and Carbon offsets. Each of these options has different challenges, costs, and absolute amounts of emission reductions that are possible. Further quantitative analysis and modeling is recommended to provide additional metrics to complement this report and inform future local action plans and goals. These goals should depend not only on the results shown in the analysis above, but also on the preferences of the city stakeholders, technical feasibility, and cost effectiveness. It is a best practice for action plans for GHG reduction initiatives to include short, medium, and long-term goals.

Given the size and influence of JMU in the City with regard to GHG emissions, interaction and coordination with JMU staff and sustainability professionals is strongly recommended and helpful for progress in reducing GHG emissions.

Given the experience over the past analyses, community and municipal GHG emissions are recommended to be assessed yearly since the data collection and analysis is relatively straightforward. It is still recommended to try to streamline and automate some of the data compilation and analysis to simplify and shorten the analysis process.

Municipal goals and plans are somewhat easier to develop since the City is mostly in control of the buildings and operations that result in emissions. The Municipal emissions contribute approximately 3.4% of the total Community emissions in 2021 for the 100-yr GWP analysis. Programs for conservation and more efficient use of electricity will have the largest impacts and save money at the same time. Geothermal HVAC systems would increase heating and cooling efficiency for municipal projects with the appropriate space and ground characteristics. Purchasing electric vehicles as some fleet vehicles reach their replacement age will reduce emissions and save money over time. Distributed renewable generation such as solar power may be a cost-effective way to reduce GHG emissions when considered for buildings with proper orientation and roof characteristics. While solar costs have decreased significantly over the past decade, each installation must be evaluated individually for its cost effectiveness and return on investment as some sites are better suited than others for this application and costs vary significantly with the scale of the project.

Significant emissions reductions are possible for both the municipality and community with the addition of renewable energy generation by the utilities. The Virginia Clean Energy Act (VCEA) of 2020 mandates a number of actions which will reduce GHG emissions including a renewable portfolio standard (RPS) for the state's electric grid. This RPS has slightly different requirements for Appalachian Power and Dominion Energy, the largest utilities in the state. Dominion Energy – which supplies the City of Harrisonburg with electricity – is required to transition its power sources to generate 41%, 79%, and 100% of its electricity from renewable sources by 2030, 2040, and 2045 respectively.¹⁷ As a result, Harrisonburg's 38% of GHG emissions from electricity will decline as Dominion Energy takes action, eventually becoming 0%. Continued support of the VCEA will help to not only ensure renewable sources for grid-supplied electricity in Harrisonburg, but will also ensure renewable sources for the majority of the 8.6 million Virginians. Thus, the City should strongly support the VCEA implementation and programs given the large contribution of electricity GHG emissions to its overall footprint.

A quick estimate suggests that meeting the 2030 and 2040 RPS goals will reduce electricity emission by 10% and 20%, respectively given the current Dominion electricity fuel mix of more than 50% fossil fuels and less than 7% renewables shown in Table 6. This emissions reduction estimate does not account for the increasing penetration of electric vehicles into the Transportation sector which was shown above in table 23 and expected to accelerate. Both hybrid and electric vehicles can already reduce vehicle GHG emissions by 40% per vehicle and additional gains will come battery technology and more renewably-generated electricity is added to the electrical grid. A more detailed model of the expected shifts in energy generation, product, and behavior can make more accurate predications over time and is recommend for future action plans to reduce GHG emissions.

The 20-yr analyses shown in this report highlight the significant role of methane for shorter term GHG reductions. Substitutions of renewable energy at the utility scale for natural gas for electricity will also reduce the natural gas leakage. City and natural gas utility initiatives to minimize local natural gas leaks for all sectors will reduce GHGs, save money, and minimize risks of explosions.

The largest opportunities for reductions are available at the Community level, but programs and initiatives at this level are more difficult since residents, businesses, and industries are in control of their own actions, buildings, technology, and vehicles. Again, these emissions may improve over time due to market penetration of more efficient vehicles and buildings and conservation, but this is not guaranteed especially if the economy grows. Therefore, programs to incentivize efficiency and conservation, initiated by the City or by other agencies, are recommended as the effects of climate change will be felt by everyone independent of the source of the emissions.

It should also be noted the actions taken to reduce emissions will have other important co-benefits. The conservation of energy or fuel saves money immediately with an infinite return on investment. The majority of GHG emissions are due to combustion processes that also create other forms of air pollution, which exacerbate both environmental and health effects. Other efficiency improvements due to new vehicles, heating systems, and novel technologies may have largest up from costs, but due to energy savings will have long-term return on investment (ROI).

There are many resources including check sheets, best-practice guides, and case studies available from other organizations and cities that can be leveraged in developing an action plan for Harrisonburg. The City's challenges are much the same as many other cities in the US. ICLEI has worked with hundreds of cities in the US and around the world and has compiled information, reports, and examples for many best practices which can vary depending on the size, location, weather, economic, housing, and commercial characteristics of a city.

6. REFERENCES:

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- ¹⁶EPA Office of Resource Conservation and Recovery, Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM), Management Practices Chapters, version 15, November 2020.
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7. APPENDIX

APPENDIX 1 – Harrisonburg Municipal Electricity Data

2021				
ACCOUNT	NAME	SERVICE ADDRESS	Total kWh	
103748-2	HBURG COMMUNITY DEVELOPMENT	345 S MAIN ST	172,480	
103748-3	HBURG COMMUNITY DEVELOPMENT	212 S MAIN ST	76,196	
103748-5	HBURG COMMUNITY DEVELOPMENT	228 S LIBERTY ST	13,833	
103748-6	HBURG COMMUNITY DEVELOPMENT	409 S MAIN ST	519,240	
103748-8	HBURG COMMUNITY DEVELOPMENT	1925 E MARKET ST STE 600	7,651	789,400
103749-3	HBURG TRANSPORTATION DEPT	473 E WASHINGTON ST	315,264	
103749-4	HBURG TRANSPORTATION DEPT	475 E WASHINGTON ST	399,288	
103749-5	HBURG TRANSPORTATION DEPT	475 E WASHINGTON ST	27,639	742,191
10456-2	HBURG FIRE DEPT	162 N LIBERTY ST	480	
10456-3	HBURG FIRE DEPT	80 MARYLAND AVE SEC LIGHT	3,195	
10456-4	HBURG FIRE DEPT	80 MARYLAND AVE	234,640	
10456-5	HBURG FIRE DEPT	399 E MOSBY RD	21,975	
10456-6	HBURG FIRE DEPT	380 PLEASANT VALLEY RD	47,928	
10456-7	HBURG FIRE DEPT	210 E ROCK ST	191,340	
10456-8	HBURG FIRE DEPT	101 N MAIN ST	1,100,592	
10456-10	HBURG FIRE DEPT	299 LUCY DR	58,157	
10456-13	HBURG FIRE DEPT	101 N MAIN ST	24	
10456-14	HBURG FIRE DEPT	90 MARYLAND AVE	6,681	
10456-15	HBURG FIRE DEPT	80 MARYLAND AVE TEMP METER	16,386	
10456-17	HBURG FIRE DEPT	101 N MAIN ST	698	1,682,096
105618-1	HBURG PURCHASING/CENTRAL STORE	2111 BEERY RD	36,391	36,391
1306-4	HBURG WATER DEPT	600 VINE ST	4,677	
1306-5	HBURG WATER DEPT	1241 OLD WINDMILL CIR	20,863	
1306-6	HBURG WATER DEPT	1002 GREYSTONE ST	3,604	
1306-7	HBURG WATER DEPT	979 SUMMIT AVE	-	
1306-10	HBURG WATER DEPT	80 GARBERS CHURCH RD	21,312	
1306-11	HBURG WATER DEPT	1751 S HIGH ST	629	
1306-17	HBURG WATER DEPT	1705 PEACH GROVE AVE	214,288	
1306-18	HBURG WATER DEPT	651 TOWER ST	121,758	
1306-23	HBURG WATER DEPT	910 UNIVERSITY BLVD	935	
1306-29	HBURG WATER DEPT	1905 E MARKET ST	114,700	
1306-33	HBURG WATER DEPT	1315 W MARKET ST	1,304	
1306-39	HBURG WATER DEPT	1600 SMITHLAND RD	26,657	
1306-40	HBURG WATER DEPT	128 CHESTNUT RIDGE DR	18,502	
1306-42	HBURG WATER DEPT	276 BLUE STONE HILLS DR	7,512	
1306-43	HBURG WATER DEPT	1790 RESERVOIR ST	166,287	
1306-44	HBURG WATER DEPT	1179 HARRISON ST	184	
1306-46	HBURG WATER DEPT	851 PORT REPUBLIC RD	1	
1306-47	HBURG WATER DEPT	2155 BEERY RD	156,640	
1306-51	HBURG WATER DEPT	1111 WILLOW SPRING RD	207	
1306-52	HBURG WATER DEPT	1491 OLD FURNACE RD	20,575	
1306-53	HBURG WATER DEPT	250 CHESTNUT RIDGE DR	70,174	
1306-54	HBURG WATER DEPT	1078 MT CLINTON PIKE	84,346	
1306-55	HBURG WATER DEPT	1300 HILLCREST DR	4,514	
	RAW WATER PUMPING STATION (82% City)	82.0%	2,508,462	
	WATER TREATMENT PLANT (82% City)	82.0%	207,099	3,775,230

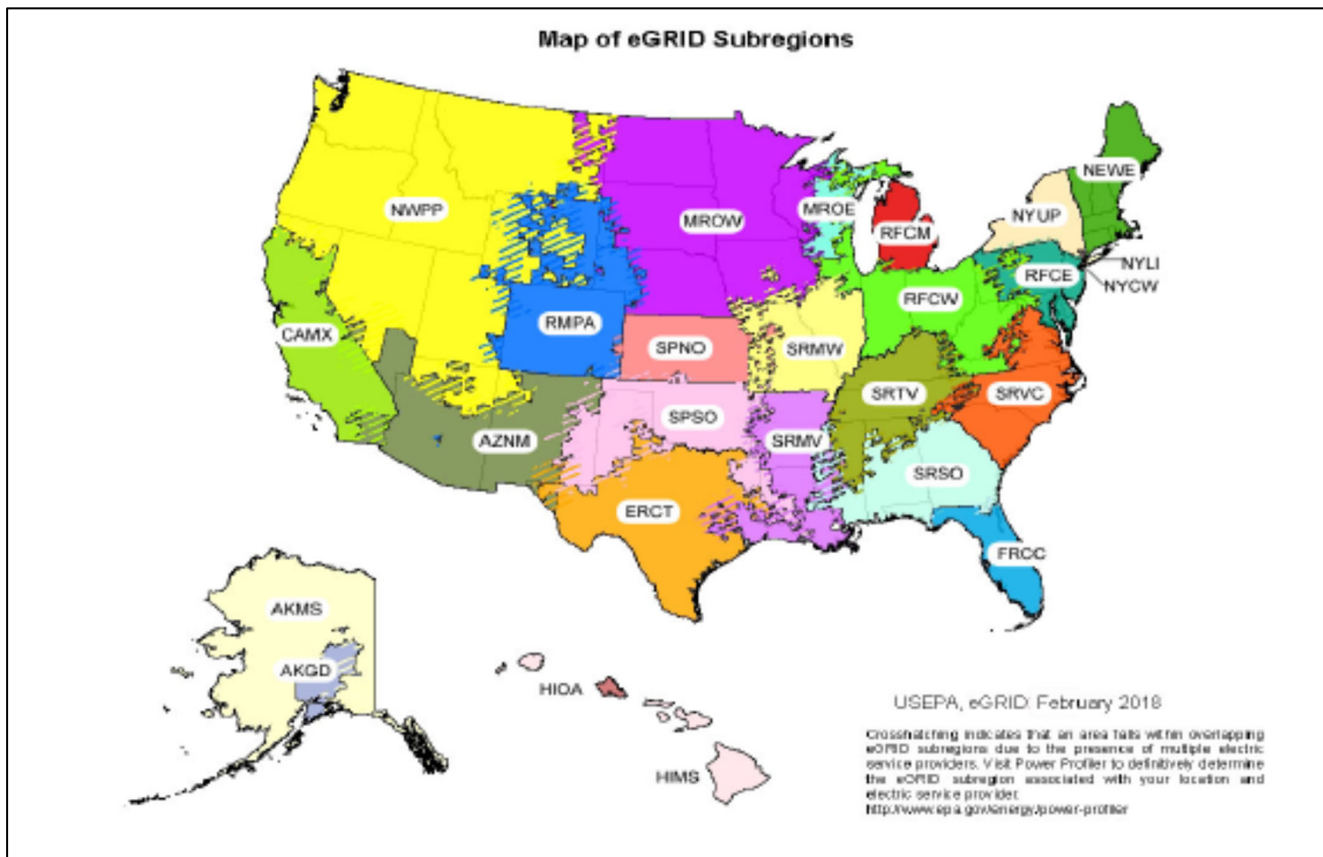
13653-3	HBURG CITY SCHOOLS	100 MARYLAND AVE	524,160	
13653-4	HBURG CITY SCHOOLS	100 MARYLAND AVE	104,588	
13653-5	HBURG CITY SCHOOLS	100 MARYLAND AVE	230,640	
13653-6	HBURG CITY SCHOOLS	1575 PEACH GROVE AVE	987,840	
13653-7	HBURG CITY SCHOOLS	1575 PEACH GROVE AVE	13,305	
13653-8	HBURG CITY SCHOOLS	1575 PEACH GROVE AVE	63,260	
13653-14	HBURG CITY SCHOOLS	375 S CARLTON ST	192,560	
13653-15	HBURG CITY SCHOOLS	375 S CARLTON ST	535,120	
13653-16	HBURG CITY SCHOOLS	375 S CARLTON ST	55,387	
13653-17	HBURG CITY SCHOOLS	400 MOUNTAIN VIEW DR	16,948	
13653-19	HBURG CITY SCHOOLS	1311 W MARKET ST	1,080,000	
13653-20	HBURG CITY SCHOOLS	451 CHICAGO AVE SEC LIGHT	6,300	
13653-21	HBURG CITY SCHOOLS	451 CHICAGO AVE	709,200	
13653-22	HBURG CITY SCHOOLS	451 CHICAGO AVE	52,166	
13653-23	HBURG CITY SCHOOLS	451 CHICAGO AVE	51,634	
13653-27	HBURG CITY SCHOOLS	1001 GARBERS CHURCH RD	1,202,880	
13653-28	HBURG CITY SCHOOLS	1001 GARBERS CHURCH RD	2,148,480	
13653-29	HBURG CITY SCHOOLS	1001 GARBERS CHURCH RD	139,776	
13653-30	HBURG CITY SCHOOLS	1575 PEACH GROVE AVE	44,371	
13653-33	HBURG CITY SCHOOLS	470 LINDA LN	2,365,440	
13653-34	HBURG CITY SCHOOLS	1 COURT SQ	214,720	
13653-35	HBURG CITY SCHOOLS	1001 GARBERS CHURCH RD	31,018	
13653-36	HBURG CITY SCHOOLS	1001 GARBERS CHURCH RD	40,960	
13653-37	HBURG CITY SCHOOLS	750 GARBERS CHURCH RD	516,300	
13653-38	HBURG CITY SCHOOLS	1001 GARBERS CHURCH RD	37,200	
13653-39	HBURG CITY SCHOOLS	1001 GARBERS CHURCH RD	23,680	
13653-40	HBURG CITY SCHOOLS	1001 GARBERS CHURCH RD	24,080	
13653-41	HBURG CITY SCHOOLS	1001 GARBERS CHURCH RD	27,815	11,439,828
14133-1	HBURG PUBLIC WORKS	901 CHICAGO AVE	15,156	
14133-2	HBURG PUBLIC WORKS	320 E MOSBY RD	36,265	
14133-3	HBURG PUBLIC WORKS	320 E MOSBY RD	113,545	
14133-4	HBURG PUBLIC WORKS	320 E MOSBY RD (Truck Heaters)	23,630	
14133-5	HBURG PUBLIC WORKS	300 E MOSBY RD (Shop)	120,506	
14133-7	HBURG PUBLIC WORKS	2055 BEERY RD (Recycle)	-	
14133-13	HBURG PUBLIC WORKS	901 CHICAGO AVE	19,400	
14133-19	HBURG PUBLIC WORKS	2115 RAMBLEWOOD RD	20,427	
14133-26	HBURG PUBLIC WORKS	335 STONE SPRING RD	432	
14133-52	HBURG PUBLIC WORKS	2055 BEERY RD (Trf Stn)	52,416	
14133-55	HBURG PUBLIC WORKS	589 UNIVERSITY BLVD	3,415	
14133-56	HBURG PUBLIC WORKS	250 RESERVOIR ST	125	405,317
13653-1	SCHOOL CROSSING LIGHT	1583 W MARKET ST STE A (Traffic Light)	24,123	
14133-9	Traffic Lights	345 S MAIN ST	310,044	
14133-10	Street Lights	345 S MAIN ST	1,445,160	
14133-11	Street Lights - Principal Arterial	345 S MAIN ST	517,320	
14133-12	Street Lights - Urban Minor Arterial	345 S MAIN ST	593,160	
14133-17	Traffic Lights	1486 W MARKET ST	2,869	
14133-24	Traffic Lights	1101 E MARKET ST	1,799	
14133-25	Traffic Lights	1911 S HIGH ST	3,987	
14133-28	Traffic Lights	671 UNIVERSITY BLVD	3,301	
14133-29	Traffic Lights	1100 S HIGH ST	2,878	
14133-30	Traffic Lights	1280 GARBERS CHURCH RD	2,132	
14133-31	Traffic Lights	2141 S MAIN ST	4,390	
14133-32	Traffic Lights	335 STONE SPRING RD	3,846	
14133-33	Traffic Lights	165 N HIGH ST	3,067	
14133-34	Traffic Lights	404 VIRGINIA AVE	3,283	
14133-36	Traffic Lights	1306 HILLSIDE AVE	3,454	
14133-37				
14133-38	Traffic Lights	2421 S MAIN ST	3,756	
14133-39	Traffic Lights	1825 S MAIN ST	5,674	
14133-40	Street Lights	460 PHEASANT RUN CIR	2,727	
14133-41	Traffic Lights	198 S MAIN ST	2,434	
14133-42	Traffic Lights	102 S MAIN ST	2,298	
14133-43	Traffic Lights	28 S MAIN ST	4,396	
14133-44	Traffic Lights	1575 PEACH GROVE AVE	2,662	
14133-45	Traffic Lights	802 S MAIN ST	3,981	
14133-46	Traffic Lights	99 BURGESS RD	4,660	
14133-47	Traffic Lights	1788 RESERVOIR ST	3,954	
14133-48	Traffic Lights	1915 RESERVOIR ST	3,858	
14133-49	Traffic Lights	2095 RESERVOIR ST	3,831	
14133-50	Traffic Lights	2396 RESERVOIR ST	2,848	
14133-51	Traffic Lights	705 S MASON ST	3,691	
14133-53	Traffic Lights	703 S MAIN ST	4,291	
14133-54		998 S MAIN ST	3,863	
14133-57		102 N MAIN ST	1,684	
14133-58		196 N MAIN ST	1,991	
14133-59		594 PORT REPUBLIC RD	5,143	
14133-61		901 CHICAGO AVE	1,789	
14133-62		1241 S MAIN ST	4,499	2,998,843
14429-5	HBURG POLICE DEPT	1016 GREENDALE RD	10,771	
14429-6	HBURG POLICE DEPT	1010 GREENDALE RD TEMP METER	107	
14429-7	HBURG POLICE DEPT	1020 GREENDALE RD	-	10,878

14511-1	DOWNTOWN PARKING SERVICES	135 N MASON ST	74,275	
14511-2	DOWNTOWN PARKING SERVICES	89 W WATER ST	133,619	
14511-3	DOWNTOWN PARKING SERVICES	135 S MAIN ST SEC LIGHT	3,180	
14511-4	DOWNTOWN PARKING SERVICES	282 N LIBERTY ST SEC LIGHT	1,440	
14511-5	DOWNTOWN PARKING SERVICES	345 S MAIN ST SEC LIGHT	7,680	
14511-6	DOWNTOWN PARKING SERVICES	44 NEWMAN AVE SEC LIGHT	2,520	
14511-8	DOWNTOWN PARKING SERVICES	48 E WATER ST SEC LIGHT	480	
14511-9	DOWNTOWN PARKING SERVICES	90 N MAIN ST SEC LIGHT	2,520	
14511-11	DOWNTOWN PARKING SERVICES	30 W BRUCE ST	434	226,148
2128-1	HBURG RECREATION DEPT	305 S DOGWOOD DR	-	
2128-2	HBURG RECREATION DEPT	1583 W MARKET ST STE B	16,736	
2128-5	HBURG RECREATION DEPT	100 MILLER CIR SEC LIGHT	4,440	
2128-6	HBURG RECREATION DEPT	1582 S MAIN ST	4,282	
2128-7	HBURG RECREATION DEPT	1582 S MAIN ST	5,098	
2128-8	HBURG RECREATION DEPT	1582 S MAIN ST SEC LIGHT	1,740	
2128-9	HBURG RECREATION DEPT	1545 HILLSIDE AVE SEC LIGHT	3,840	
2128-10				
2128-12	HBURG RECREATION DEPT	909 RESERVOIR ST	16,730	
2128-14	HBURG RECREATION DEPT	620 SIMMS AVE	15,959	
2128-15	HBURG RECREATION DEPT	401 E WASHINGTON ST	4,248	
2128-16	HBURG RECREATION DEPT	901 CHICAGO AVE	19,549	
2128-17	HBURG RECREATION DEPT	305 S DOGWOOD DR	1,848	
2128-18	HBURG RECREATION DEPT	305 S DOGWOOD DR	310,120	
2128-19	HBURG RECREATION DEPT	305 S DOGWOOD DR	207,900	
2128-20	HBURG RECREATION DEPT	305 S DOGWOOD DR	1,485	
2128-22	HBURG RECREATION DEPT	680 GARBERS CHURCH RD	78,720	
2128-24	HBURG RECREATION DEPT	1582 S MAIN ST	13,877	
2128-25	HBURG RECREATION DEPT	1412 SMITHLAND RD	39,212	
2128-26	HBURG RECREATION DEPT	680 GARBERS CHURCH RD	62,700	
2128-29	HBURG RECREATION DEPT	305 S DOGWOOD DR	-	
2128-31	HBURG RECREATION DEPT	1583 W MARKET ST	2,366	
2128-32	HBURG RECREATION DEPT	501 HILLANDALE AVE TEMP METER	-	
2128-33	HBURG RECREATION DEPT	501 HILLANDALE AVE TEMP METER	-	
2128-34	HBURG RECREATION DEPT	461 2ND ST	6,209	
2128-35	HBURG RECREATION DEPT	1542 SMITHLAND RD	6,642	
2128-37	HBURG RECREATION DEPT	1545 HILLSIDE AVE	5,009	
2128-38	HBURG RECREATION DEPT	1545 HILLSIDE AVE	2,522	
2128-39	HBURG RECREATION DEPT	1545 HILLSIDE AVE	8,750	
2128-40	HBURG RECREATION DEPT	1545 HILLSIDE AVE	14,500	
2128-45	HBURG RECREATION DEPT	501 HILLANDALE AVE	26,720	
2128-49	HBURG RECREATION DEPT	177 S MAIN ST	5,037	
2128-50	HBURG RECREATION DEPT	188 N LIBERTY ST	4,500	
2128-53	HBURG RECREATION DEPT	1950 THOMAS BOWERS CIR	2,281	
2128-55	HBURG RECREATION DEPT	431 E WASHINGTON ST TEMP METER	2	
2128-57	HBURG RECREATION DEPT	431 E WASHINGTON ST SEC LIGHT	2,400	
2128-58	HBURG RECREATION DEPT	620 SIMMS AVE	569,856	
2128-61	HBURG RECREATION DEPT	431 E WASHINGTON ST	4,528	
2128-62	HBURG RECREATION DEPT	2181 RAMBLEWOOD RD	40,512	
2128-63	HBURG RECREATION DEPT	309 S DOGWOOD DR	9,600	
2128-64	HBURG RECREATION DEPT	317 S MAIN ST SEC LIGHT	480	
2128-65	HBURG RECREATION DEPT	246 S LIBERTY ST	243	
2128-66	HBURG RECREATION DEPT	248 S LIBERTY ST	39	
2128-67	HBURG RECREATION DEPT	252 S LIBERTY ST	4	1,520,684
9305-1	HBURG RHAM REG SEWER AUTH	1321 S DOGWOOD DR	881	
HBURG RHAM REG SEWER AUTH FACILITY (56.4% City)		56.4%	7,950,621	7,951,502
112263-1	HRECC	653 Tower St (Radio Tower)	119,685	
112263-2	HRECC	1575 Peach Grove Ave (Radio Tower)	41,837	
112263-5	HRECC	420 Mt Clinton Pike (Radio Shop)	40,560	
112263-6	HRECC	424 Mt Clinton Pike (Radio Storage Sho	2,536	204,618
			31,783,126	31,783,126

APPENDIX 2 –EPA eGRID Regional Electricity Emission Rates (2020)

1. Subregion Output Emission Rates (eGRID2020)																
eGRID subregion acronym	eGRID subregion name	Total output emission rates lb/MWh							Non-baseload output emission rates lb/MWh							Grid Gross Loss (%)
		CO ₂	CH ₄	N ₂ O	CO ₂ e	Annual NO _x	Ozone Season NO _x	SO ₂	CO ₂	CH ₄	N ₂ O	CO ₂ e	Annual NO _x	Ozone Season NO _x	SO ₂	
AKGD	ASCC Alaska Grid	1,097.6	0.100	0.014	1,104.2	6.0	5.9	0.6	1,315.1	0.126	0.017	1,323.4	6.8	7.0	0.7	5.5%
AKMS	ASCC Miscellaneous	534.1	0.027	0.005	536.1	8.3	8.0	0.7	1,517.7	0.066	0.012	1,522.8	24.2	24.8	2.1	5.5%
AZNM	WECC Southwest	846.6	0.054	0.007	850.2	0.5	0.5	0.2	1,368.6	0.090	0.013	1,374.6	0.8	0.8	0.2	5.3%
CAMX	WECC California	513.5	0.032	0.004	515.5	0.5	0.5	0.0	1,006.5	0.053	0.007	1,009.9	0.9	0.9	0.1	5.3%
ERCT	ERCOT All	818.6	0.052	0.007	822.0	0.5	0.5	0.5	1,296.6	0.086	0.012	1,302.3	0.8	0.7	0.9	5.2%
FRCC	FRCC All	835.1	0.049	0.006	838.2	0.3	0.3	0.2	1,011.0	0.052	0.007	1,014.4	0.3	0.3	0.2	5.3%
HIMS	HICC Miscellaneous	1,143.2	0.110	0.017	1,151.1	7.5	7.3	3.9	1,542.1	0.134	0.022	1,551.8	11.4	11.4	5.0	5.6%
HIOA	HICC Oahu	1,653.0	0.178	0.027	1,665.5	3.8	3.8	6.8	1,753.5	0.175	0.027	1,766.0	4.5	4.5	7.9	5.6%
MROE	MRO East	1,526.4	0.139	0.020	1,535.8	1.0	1.0	0.4	1,628.9	0.143	0.021	1,638.5	1.1	1.1	0.4	5.3%
MROW	MRO West	979.5	0.104	0.015	986.6	0.7	0.8	0.9	1,810.0	0.185	0.027	1,822.5	1.3	1.3	1.6	5.3%
NEWE	NPCC New England	528.2	0.074	0.010	533.0	0.4	0.4	0.1	882.5	0.070	0.009	886.9	0.4	0.4	0.1	5.3%
NWPP	WECC Northwest	600.0	0.056	0.008	603.8	0.5	0.5	0.3	1,653.0	0.159	0.023	1,663.8	1.5	1.5	0.8	5.3%
NYCW	NPCC NYC/Westchester	634.6	0.022	0.003	636.0	0.2	0.2	0.0	970.2	0.021	0.002	971.4	0.4	0.4	0.0	5.3%
NYLI	NPCC Long Island	1,203.9	0.138	0.018	1,212.7	0.9	0.8	0.1	1,260.6	0.034	0.004	1,262.6	0.8	0.8	0.1	5.3%
NYUP	NPCC Upstate NY	233.5	0.016	0.002	234.5	0.1	0.1	0.0	877.9	0.042	0.005	880.5	0.4	0.4	0.1	5.3%
PRMS	Puerto Rico Miscellaneous	1,602.2	0.085	0.014	1,608.5	3.9	3.9	4.3	1,673.3	0.070	0.013	1,678.8	4.6	4.5	5.5	0.0%
RFCE	RFC East	652.5	0.045	0.006	655.4	0.3	0.3	0.3	1,233.4	0.085	0.012	1,239.1	0.7	0.7	0.7	5.3%
RFCM	RFC Michigan	1,153.1	0.101	0.014	1,159.8	0.6	0.7	0.8	1,725.7	0.163	0.023	1,736.5	1.1	1.1	1.6	5.3%
RFCW	RFC West	985.0	0.086	0.012	990.8	0.6	0.6	0.7	1,810.4	0.173	0.025	1,822.2	1.2	1.1	1.3	5.3%
RMPA	WECC Rockies	1,144.8	0.101	0.014	1,151.6	0.6	0.6	0.3	1,651.9	0.131	0.019	1,660.8	0.9	0.9	0.4	5.3%
SPNO	SPP North	954.0	0.100	0.014	960.8	0.5	0.5	0.2	1,969.9	0.205	0.030	1,983.9	1.0	1.0	0.4	5.3%
SPSO	SPP South	931.8	0.060	0.009	935.8	0.6	0.7	0.6	1,514.1	0.100	0.014	1,520.8	1.2	1.2	1.1	5.3%
SRMV	SERC Mississippi Valley	740.4	0.032	0.004	742.4	0.6	0.7	0.5	1,137.4	0.055	0.008	1,141.0	0.9	1.1	1.0	5.3%
SRMW	SERC Midwest	1,480.7	0.156	0.023	1,491.4	1.1	1.2	2.6	1,866.5	0.194	0.028	1,879.6	1.6	1.6	2.9	5.3%
SRSO	SERC South	860.2	0.060	0.009	864.2	0.4	0.4	0.2	1,336.9	0.094	0.013	1,343.2	0.7	0.6	0.3	5.3%
SRTV	SERC Tennessee Valley	834.2	0.075	0.011	839.2	0.4	0.4	0.5	1,511.8	0.135	0.019	1,521.0	0.7	0.6	0.9	5.3%
SRVC	SERC Virginia/Carolina	623.1	0.050	0.007	626.3	0.3	0.3	0.2	1,323.9	0.114	0.016	1,331.3	0.7	0.8	0.4	5.3%
U.S.		818.3	0.065	0.009	822.6	0.5	0.5	0.5	1,399.6	0.109	0.016	1,406.8	0.9	0.9	0.8	5.3%

Created: 1/27/2022



APPENDIX 3 – ClearPath Transportation Factor Sets

(2021 factor set data not yet released)

Category	2016	2019	2020
Gas Passenger Vehicle Fuel Economy (MPG)	23.95689	24.37713	24.37713
Gas Passenger Vehicle (g CH4/mi)	0.0196	0.0183	0.0180
Gas PassengerVehicle (g N2O/mi)	0.0119	0.0083	0.0074
Gas Light Truck Fuel Economy (MPG)	17.39756	17.86788	17.86788
Gas Light Truck (g CH4/mi)	0.0223	0.0193	0.0187
Gas Light Truck (g N2O/mi)	0.0214	0.0148	0.0132
Gas Heavy Truck Fuel Economy (MPG)	5.35883	5.371652	5.377347
Gas Heavy Truck (g CH4/mi)	0.1047	0.0785	0.0719
Gas Heavy Truck g N2O/mi	0.0726	0.0633	0.0611
Gas Transit Bus Fuel Economy (MPG)	17.39756	17.86788	17.86788
Gas Transit Bus (g CH4/mi)	0.0223	0.0193	0.0187
Gas Transit Bus (g N2O/mi)	0.0214	0.0148	0.0132
Gas Para Transit Bus Fuel Economy (MPG)	17.39756	17.86788	17.86788
Gas Para Transit Bus (g CH4/mi)	0.0223	0.0193	0.0187
Gas Para Transit Bus (g N2O/mi)	0.0214	0.0148	0.0132
Gas Motorcycle Fuel Economy (MPG)	23.95689	24.37713	24.37713
Gas Motorcycle (g CH4/mi)	0.0196	0.0183	0.018
Gas Motorcycle (g N2O/mi)	0.0119	0.0083	0.0074

Category	2016	2019	2020
Diesel Passenger Vehicle Fuel Economy (MPG)	23.95689	24.37713	24.37713
Diesel Passenger Vehicle (g CH4/mi)	0.0005	0.0005	0.0005
Diesel PassengerVehicle (g N2O/mi)	0.001	0.001	0.001
Diesel Light Truck Fuel Economy (MPG)	17.39756	17.86788	17.86788
Diesel Light Truck (g CH4/mi)	0.001	0.001	0.001
Diesel Light Truck (g N2O/mi)	0.0015	0.0015	0.0015
Diesel Heavy Truck Fuel Economy (MPG)	6.154184	6.392468	6.478112
Diesel Heavy Truck g CH4/mi	0.0051	0.0051	0.0051
Diesel Heavy Truck (g N2O/mi)	0.0048	0.0048	0.0048
Diesel Transit Bus Fuel Economy (MPG)	17.39756	17.86788	17.86788
Diesel Transit Bus (g CH4/mi)	0.001	0.001	0.001
Diesel Transit Bus (g N2O/mi)	0.0015	0.0015	0.0015
Diesel Para Transit Bus Fuel Economy (MPG)	17.39756	17.86788	17.86788
Diesel Para Transit Bus (g CH4/mi)	0.001	0.001	0.001
Diesel Para Transit Bus g N2O/mi(g N2O/mi)	0.0015	0.0015	0.0015
Diesel Motorcycle Fuel Economy (MPG)	23.95689	24.37713	24.37713
Diesel Motorcycle (g CH4/mi)	0.0005	0.0005	0.0005
Diesel Motorcycle (g N2O/mi)	0.001	0.001	0.001