Community Greenhouse Gas Inventory for Morgantown, West Virginia

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Cover photo credit: Julie Black

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EQUATIONS

ABBREVIATIONS

CH_4	Methane
CO_2	Carbon dioxide
eGRID	Emissions and Generation Resource Integrated Database
ESPC	Energy-saving performance contract
GHG	Greenhouse gas
GWP	Global warming potential
ICLEI	International Council for Local Environmental Initiatives
kWh	Kilowatt-hour
LPG	Liquefied petroleum gas
LRTP	Long Range Transportation Plan
Mcf	Thousand cubic feet
MMBtu	Million British thermal units
MMMPO	Morgantown Monongalia Metropolitan Planning Organization
MT	Metric ton
MT CO_2e	Metric Ton Carbon Dioxide Equivalent
MT/kg	Metric ton per kilogram
MUB	Morgantown Utility Board
MW	Megawatt
MWh	Megawatt-hour
N_2O	Nitrous oxide
NA	Not Applicable
NERC	North American Electric Reliability Corporation
PSC	Public Service Commission
RFCw	Reliability First Corporation west
US	United States
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
VMT	Vehicle miles traveled
WVDEP	West Virginia Division of Environmental Protection
WVDEP DAQ	West Virginia Department of Environmental Protection Division of Air Quality
WVU	West Virginia University

EXECUTIVE SUMMARY

This report calculates a community-wide 2012 baseline inventory of GHG emissions for the city of Morgantown, West Virginia, including West Virginia University. This inventory lays the foundation for identifying the most promising energy-saving policies and projects that will save the City, its residents, and its businesses money while reducing GHG emissions and other associated pollution.

In this report, we focus on GHG emissions that occur as a result of activities by community members, whether or not the emissions occur inside or outside city limits; however, for the built environment, we also separately calculate source-based emissions—those that take place within city limits.

This inventory references the International Council for Local Environmental Initiatives' United States Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Our goal was for this inventory, whenever possible, to be consistent with this protocol.

The five basic emission generating activities include: (1) use of electricity by the community, (2) use of fuel in residential and commercial stationary combustion equipment, (3) use of energy in drinking water and wastewater treatment and distribution, (4) generation of solid waste by the community, and (5) on-road passenger and freight motor vehicle travel.

Emissions associated with community "activities" generated 805,694 MT CO_2e in 2012, while emissions associated with community "sources" generated 691,573 MT CO_2e.

Table ES-1: Summary of source- and activity-based emissions (MT CO_2e)

Sector	Source-based	Activity-based
Built environment		
Electricity	613,298	347,434
Natural gas and other stationary fuels	78,275	96,314
Subtotal, built environment	**691,573**	**443,748**
Water and wastewater	N/A	6,982
Solid waste	N/A	9,656
Transportation	N/A	345,308
Total	**691,573**	**805,694**

This inventory is important because it identifies greenhouse gas reduction opportunities and contains a large amount of information that can be leveraged by the Morgantown community to develop policies and programs to reduce emissions. We recommend that the information contained within this report be referenced as the community and policy makers consider options. Besides energy conservation benefits that could be achieved by targeting sectors that consume large amounts of energy, non-energy benefits could also be realized through the same programs and policies. These additional benefits include improved human health through reductions in air pollution as well as community economic benefits because Morgantown would be a more attractive place to live.

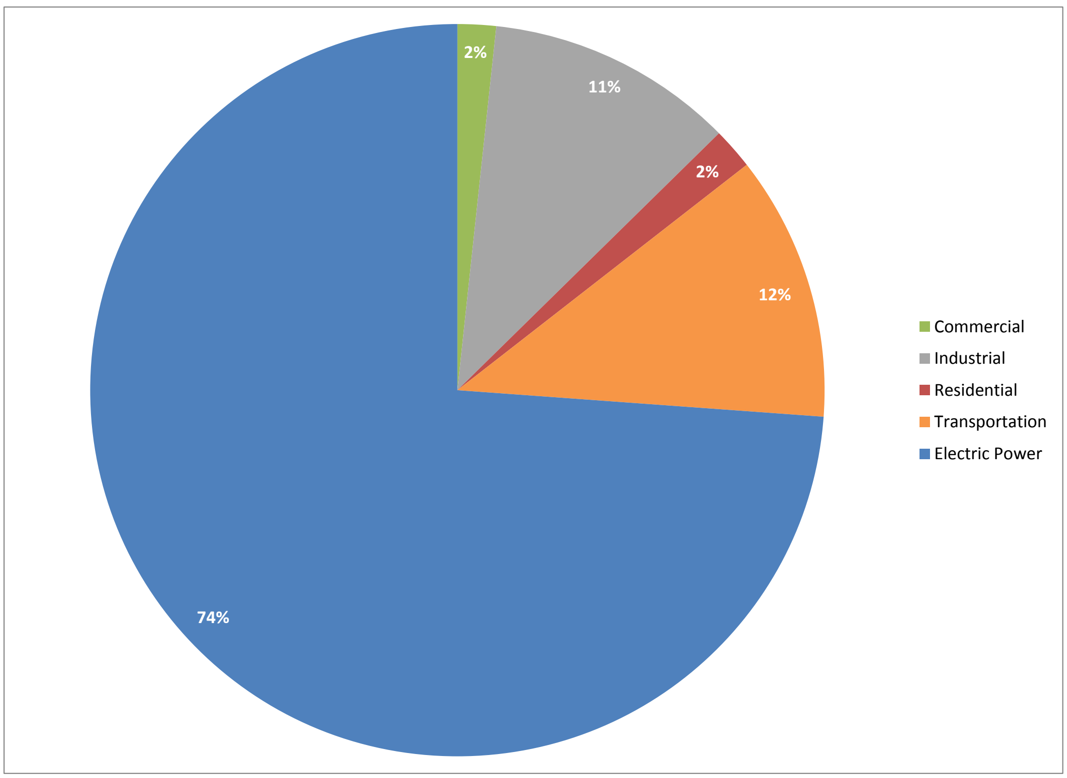
This baseline GHG inventory was the first phase of a broader three-phase project to identify energy-saving opportunities in Morgantown that, when implemented, will save money, reduce GHG emissions, and show progress toward initiatives that the City of Morgantown supports. Phase 2, which has been funded by the Appalachian Stewardship Foundation and will be completed in May 2015, will quantify opportunities for residents and businesses to reduce energy consumption and associated greenhouse gas emissions.

1. INTRODUCTION

Reducing greenhouse gas (GHG) emissions requires actions at the international, national, state, and local levels. This report calculates a community-wide 2012 baseline inventory of GHG emissions for the city of Morgantown, West Virginia, including West Virginia University (WVU). This inventory lays the foundation for identifying the most promising energy-saving policies and projects that will save the City, its residents, and its businesses money while reducing GHG emissions and other associated pollution.

After peaking at 7,325 million metric tons (MT) of carbon dioxide equivalents (CO_2e) in 2007, GHG emissions in the United States (US) dropped to 6,526 MT CO_2e in 2012 (USEPA, 2014a). At the state level, carbon dioxide (CO_2) emissions from fossil fuel combustion in West Virginia totaled 96 million MT CO_2e in 2011.[1] As shown in Figure 1, almost three-quarters of West Virginia's CO_2 emissions come from generating electricity—mostly from coal. For comparison, GHG emissions calculated in this report for the Morgantown community total approximately 0.8 million MT CO_2e in 2012—just under 1% of the state total.

Figure 1: Share of West Virginia's fossil fuel CO_2 emissions by sector



Source: USEPA (undated).

In this report, we focus on GHG emissions that occur as a result of activities by community members, whether or not the emissions occur inside or outside city limits; however, for the built environment, we also separately calculate source-based emissions—those that take place within city limits.

While special consideration is given to emissions from City and WVU operations, this community-wide inventory also include emissions from energy use in homes and fuels used during transportation. As such, it

[1] 2011 is the latest year for which these data are available. State-level summary data are not available for GHGs other than CO_2 (USEPA, Undated).

can become a useful planning tool in developing mitigation actions across the entire community, and not just for City and university efforts (USEPA, 2014b).

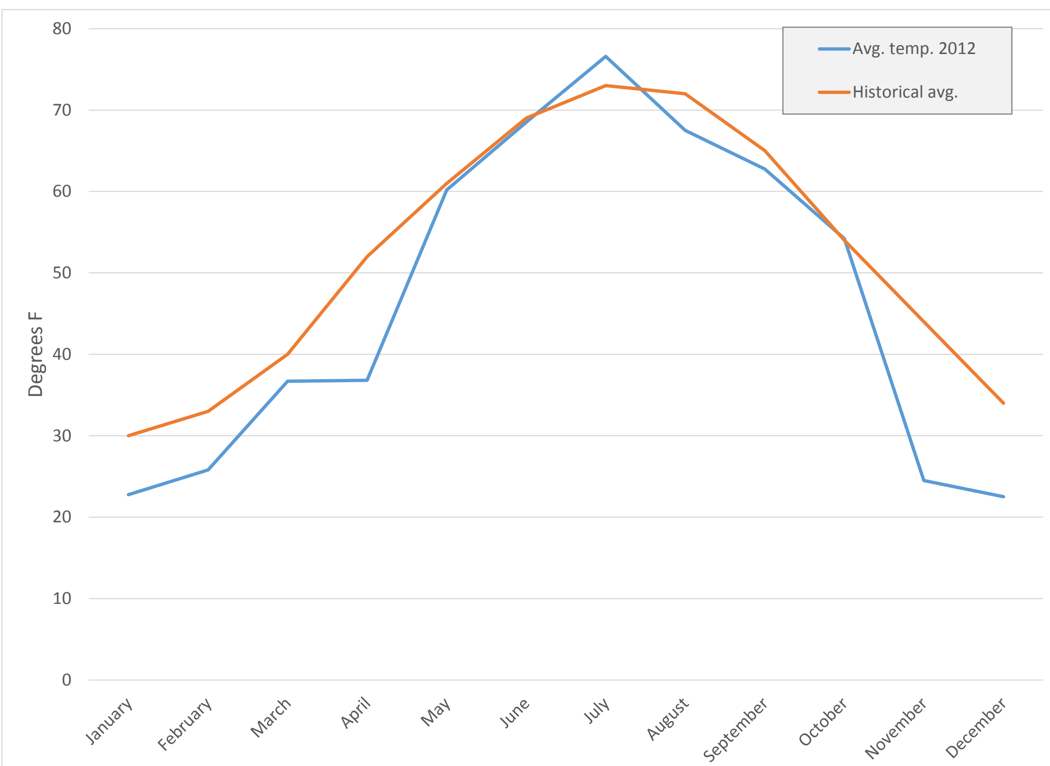
The selection of 2012 as the baseline year was based on considerations recommended by the United States Environmental Protection Agency (USEPA) (USEPA, 2014c). The first consideration is whether data exist for the selected year. The year 2012 was the last full calendar year prior to the project start date of June 1, 2013.

The second consideration focuses on whether or not the chosen baseline year would be considered representative in terms of average weather or historical energy consumption. In 2012, both average temperature and total precipitation were below the historical average. Figure 2 shows the average temperature by month for 2012 and the historical average by month for Morgantown. On average across all of 2012, Morgantown's temperature was 5 degrees Fahrenheit cooler than the historical average (US Climate Data, 2014).

Figure 3 shows the total precipitation for 2012 and the historical average by month for Morgantown. Total Morgantown precipitation in 2012 was 34.5 inches, which is 8.6 inches less than the historical average of 43.1 inches (US Climate Data, 2014). Other notable weather events experienced in 2012 include the derecho in June and Superstorm Sandy in October. Historical energy consumption data were not available to compare against the data collected for 2012. The comparison of historical versus 2012 temperature and precipitation data, however, suggests that the 2012 data is likely to be reasonably representative.

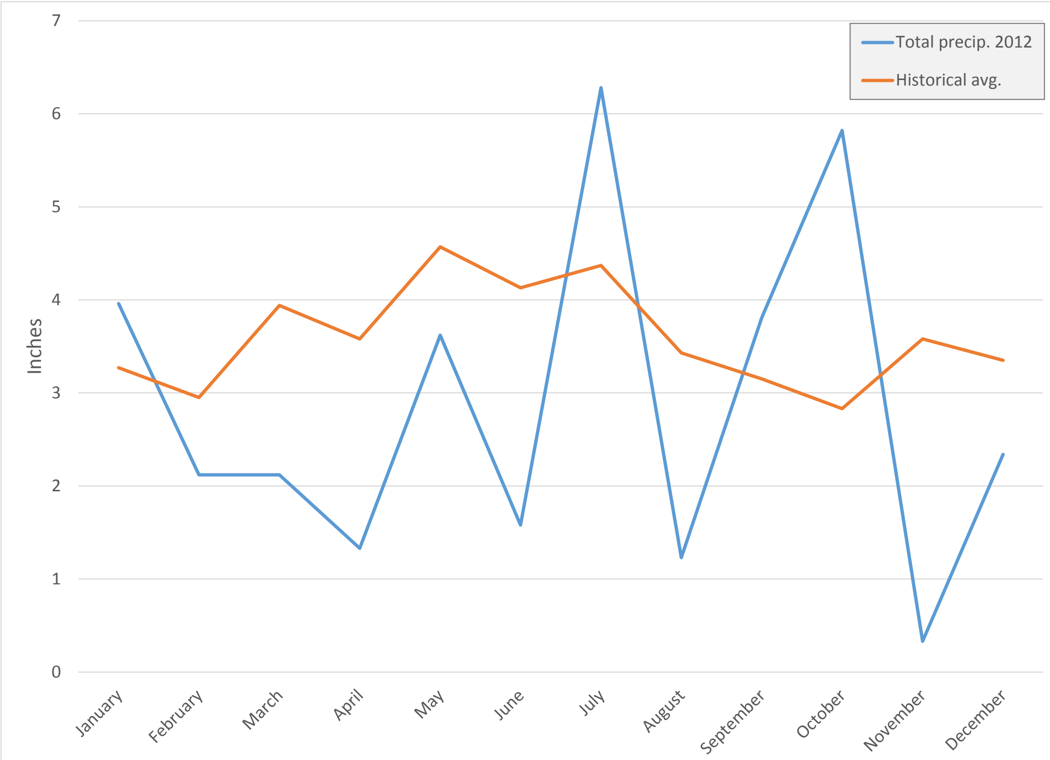
The third consideration suggests that the chosen baseline year be coordinated with baseline years used in other inventories. Because this GHG inventory is the first of its kind within the city of Morgantown and, as far as we know, across West Virginia, we are satisfied that 2012 is an appropriate starting point.

Figure 2: Average (2012) and historical temperature by month for Morgantown (degrees Fahrenheit)



Source: US Climate Data (2014). Note: The historical average includes 2005 through 2012.

Figure 3: Total (2012) and historical precipitation by month for Morgantown (inches)



Source: US Climate Data (2014). Note: The historical average includes 2005 through 2012.

This inventory references the International Council for Local Environmental Initiatives' (ICLEI's) US Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions ("Community Protocol"). ICLEI is the leading global network devoted to local governments engaged in sustainability, climate protection, and clean energy initiatives. It is a member organization made up of over 1,000 local governments worldwide. Members gain access to software, technical tools, and technical assistance to support their efforts throughout projects, including GHG inventories. (ICLEI, 2014a)

The City of Morgantown is not a member of ICLEI, and therefore the project team was unable to access many of the tools and support that ICLEI offers. Instead, we used the Community Protocol as a reference for our data collection and calculations. Our goal was for this inventory, whenever possible, to be consistent with this protocol.

The project team also used USEPA's State and Local Climate Energy Program's Community Greenhouse Gas Inventory Tool, which is a Microsoft Excel spreadsheet that assists users in converting GHG-generating activity data into emissions using local power generation characteristics or other appropriate emission factors. This tool was developed to support communities across the US to evaluate their GHG emissions.

1.1 The Community Protocol

The Community Protocol provides a framework for communities to account for and report on GHG emissions. Establishing the baseline inventory is an important first step as it can be used to measure reductions in GHG emissions associated with various local government and community-implemented reduction strategies. Local governments may choose to develop a community GHG baseline emissions inventory because it:

- informs climate action planning;
- demonstrates accountability and leadership;
- tracks GHG emissions performance over time;
- motivates community action;
- recognizes GHG emissions performance relative to similar communities;
- enables aggregation of GHG emissions data across regions; and
- demonstrates compliance with regulations, voluntary agreements, and market standards (where applicable). (ICLEI, 2012a)

This protocol is unique because it establishes requirements and best practices for estimating emissions at the community level. Other protocols exist for individual companies, projects, or government entities that provide accounting methodologies for reporting GHG emissions at the entity level. In contrast, a community protocol provides a more robust and complete look into emissions across geopolitically defined areas using community-wide data sets. ICLEI has made a push toward these all-encompassing GHG inventories because they provide a better picture of current trends and can inform decision makers as they build solutions. Yet, limitations remain. Some emissions cannot be estimated due to a lack of valid methods, a lack of emissions data, or other reasons (ICLEI, 2012a). Still, community-focused inventories offer a very comprehensive look into GHG emissions.

An important component of the Community Protocol that can help to reduce issues associated with double counting involves reporting activity- and source-based emissions separately (ICLEI, 2012a). Source-based emissions include those generated within the city boundaries, whether or not the emissions are associated with city residents. For example, the Morgantown Energy Associates power plant, located within the city, generates significant emissions, but the electricity generated at this plant far exceeds the electricity demand for the city.

In contrast, activity-based emissions include those attributed to city residents, whether or not the actual GHG emissions occur within the city. For example, methane is generated at the landfill that accepts Morgantown's waste; these activity-based emissions are associated with the Morgantown community even though they are generated far from the city boundary.

Throughout this report, we carefully distinguish between source- and activity-based emissions because they answer different questions. While we calculate activity-based emissions for all sectors, we only calculate source-based activities for the built environment.

GHG emissions can be summed together within the source or activity category but cannot be summed across categories without double-counting some emissions. As a result, for some sectors, we calculate two totals—each of which provides unique and useful information.

The Community Protocol requires that five basic emissions-generating activities be addressed in order for a GHG inventory to be considered protocol-compliant. These activities were chosen because:

- local governments typically have a significant influence over the emissions-generating activity,
- data needed to estimate emissions are reasonably available,
- emissions associated with the activity tend to be significant in magnitude, and
- the activity is common across US communities. (ICLEI, 2012a)

The five basic emission generating activities include:

1. **Use of electricity by the community**, which includes power plant emissions associated with generating electricity used within the jurisdictional boundary of the community, regardless of the location of the electricity generation facility.
2. **Use of fuel in residential and commercial stationary combustion equipment**, which includes combustion emissions associated with fuels used in residential and commercial stationary applications (e.g., natural gas used in boilers and furnaces) within the jurisdictional boundary of the community, excluding fuels used for production of electricity or district energy.
3. **Use of energy in drinking water and wastewater treatment and distribution**, which includes emissions associated with energy used in the treatment and delivery of drinking water used in the community and in the collection and treatment of wastewater used in the community, regardless of the location of the water and wastewater infrastructure.
4. **Generation of solid waste by the community**, which includes the collection, transportation, and end-of-life emissions (i.e., projected future methane emissions) associated with disposal of waste generated by members of the community during the analysis year, regardless of the disposal location or method.
5. **On-road passenger and freight motor vehicle travel**, which includes emissions associated with transportation fuels used by passenger cars, passenger trucks, motorcycles, and freight motor vehicles. (ICLEI, 2012a)

1.2 About Morgantown

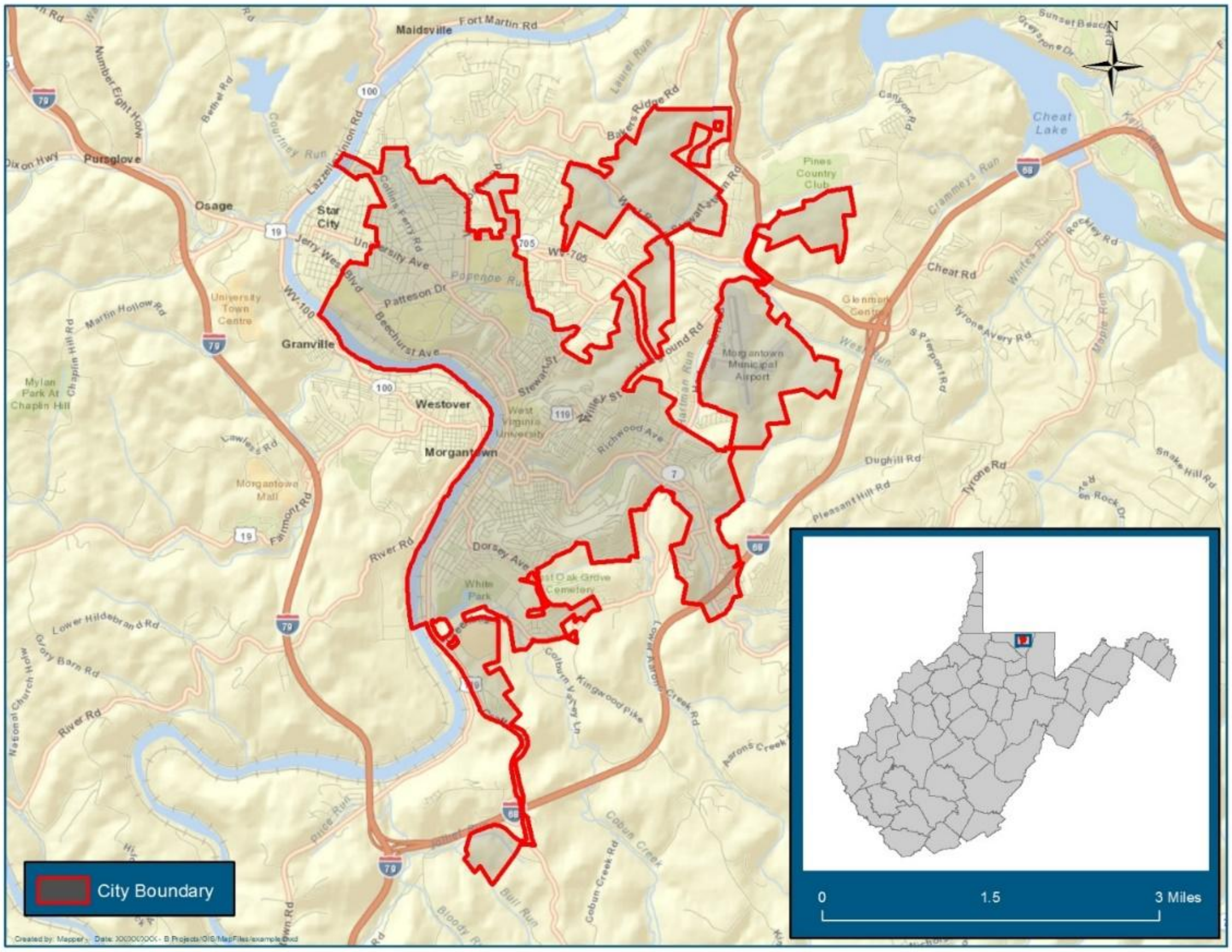
The City of Morgantown is the county seat of Monongalia County and is located along the banks of the Monongahela River (Figure 4). The city is one of the major growth areas in West Virginia and has experienced continued population growth over the last 20 years. Between 2000 and 2010 and out of the ten largest cities in West Virginia, Morgantown was one of only three cities that showed a positive population growth—just over 10 percent (City of Morgantown, 2013a).

The city and county have consistently seen some of the lowest unemployment rates in the state. Morgantown hosts West Virginia's largest institution of higher education, WVU, and is the medical, cultural, and commercial hub of the region. The city of Morgantown's population in 2012 was 30,273, a 4.7 percent increase over the 2010 population of 28,827 (US Census Bureau, 2014). The daytime population is approximately 70,000 (City of Morgantown, 2014a).

Morgantown experiences seasonal shifts in population due to the presence of WVU. Between 2000 and 2010, WVU's enrollment increased by 33.3 percent (City of Morgantown, 2013a). In fall 2012, the WVU student population topped out at 29,706, which was the highest enrollment ever (West Virginia University, 2014a). The doubling of the Morgantown population during times when WVU is in session significantly increases the GHG emissions generated within the city.

With land area comprising approximately 10.5 square miles and a population density approaching 2,900 persons per square mile, Morgantown is one of the most densely populated cities in West Virginia (City of Morgantown, 2013b). Although its current population density is slightly less than the 3,000 persons per square mile median density of US cities, the city's look and feel would make one conclude that the population density is much higher (City of Morgantown, 2013a). This can be attributed to the fact that 40 percent of the city's land is either farmland owned and maintained by WVU or part of the Morgantown Municipal Airport. Since 2000, Morgantown has only expanded by approximately 125 acres (City of Morgantown, 2013a).

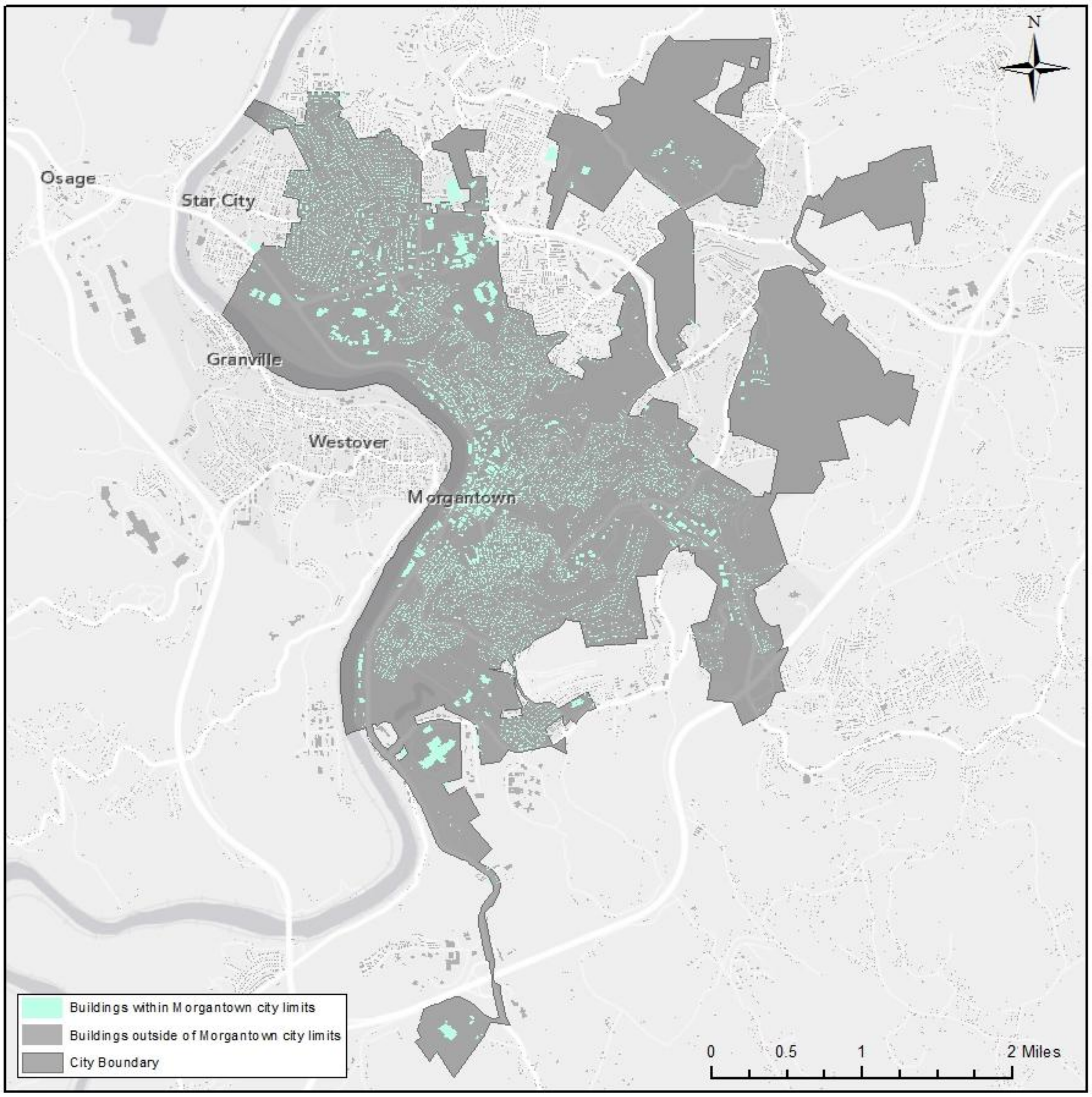
Figure 4: City of Morgantown



2. BUILT ENVIRONMENT

The built environment includes the structures that provide living and working spaces for community activities. GHG emissions attributed to the built environment include those from the residential, commercial, industrial, and government sectors as a result of energy use (ICLEI, 2012b). In the following sections, we calculate GHG emissions from electricity and stationary fuels, such as natural gas, within the built environment. Figure 5 illustrates the built environment within and outside of the city of Morgantown.

Figure 5: Distribution of the built environment within and outside of the city of Morgantown



Source: Monongalia county building footprint data from MMMPO (2013).

2.1 Electricity

In 2010, West Virginia ranked second among all other US states in total coal production (Bowen, 2012) and, in 2013, produced 96% of its electricity from coal-fired power plants (Energy Information Administration, 2013a). In fact, there are three coal-fired power plants within a ten-mile radius of the city, with one, the Morgantown Energy Associates facility, located within city limits (USEPA, 2009).

It is important to distinguish between in-boundary GHG emissions (source-based emissions) and in-boundary activities that result in GHG emissions within or outside of city limits (activity-based emissions). For example, the use of electricity by the community where the point of production is outside of the community would be considered activity-based GHG emissions. In contrast, emissions associated with electricity generated within city limits, such as at the Morgantown Energy Associates plant, would be considered source-based emissions (Table 1).

Table 1: Types of source- versus activity-based emissions in the electricity sector

Source-based emissions	Activity-based emissions
• Emissions generated by the Morgantown Energy Associates power plant	• Emissions generated by power plants that provide electricity used within the community boundary • Associated transmission, distribution, and upstream emissions

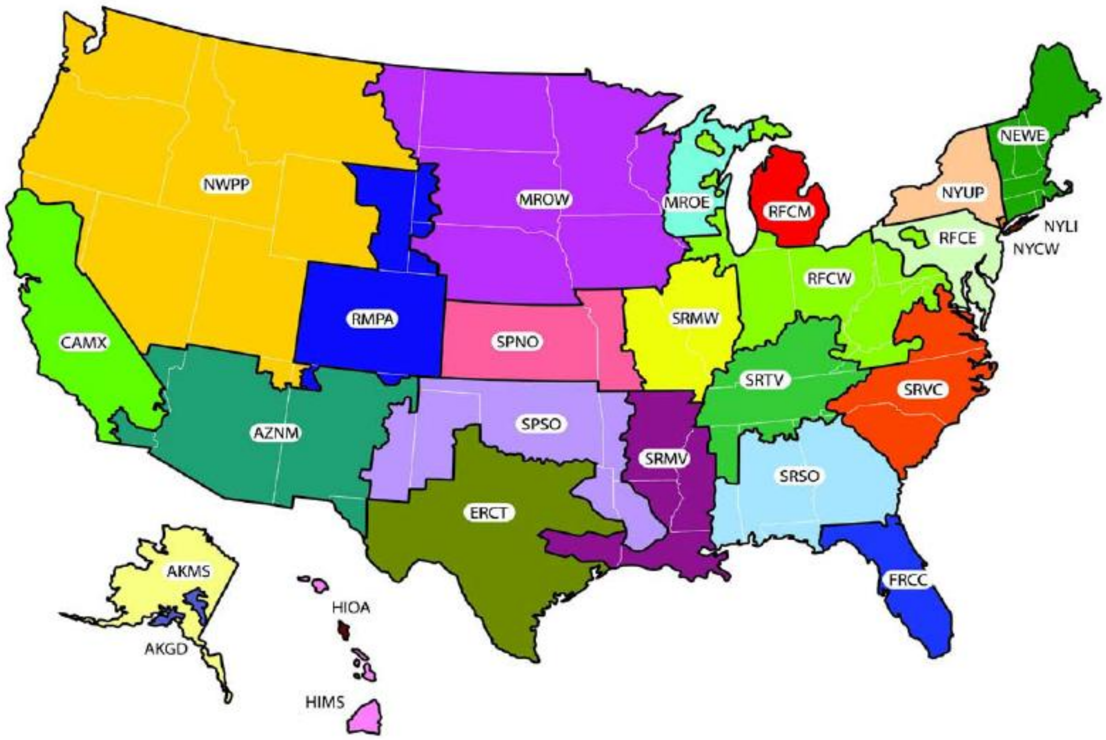
The primary activities associated with the electricity sector include generation, transmission, and distribution. CO_2 makes up the vast majority of GHG emissions from the sector, but smaller amounts of methane (CH_4) and nitrous oxide (N_2O) are also emitted. The gases are released at different levels depending on the primary fuel source used to produce electricity. Coal combustion is generally more carbon-intensive than burning natural gas or petroleum for electricity. Although coal accounts for about 75% of CO_2 emissions from the sector across the US, it fuels only about 39% of the electricity generated (USEPA, 2014d).

The Monongahela Power Company ("Mon Power"), a subsidiary of FirstEnergy, is the local electric utility company for the region. FirstEnergy is headquartered in Akron, Ohio and is one of the largest investor-owned electric systems in the US, with a diverse generating fleet containing more than 17,500 MW of generation capacity and serving approximately 6 million customers. FirstEnergy also participates in competitive electricity sales and transmission operations over its 10 companies (FirstEnergy, 2014).

West Virginia is a member of the PJM Interconnection, the regional transmission organization that coordinates the movement of wholesale electricity in all or parts of a 13-state region, including the District of Columbia (PJM, 2014). PJM is a neutral, independent party that operates the competitive wholesale electricity market and manages the high-voltage electricity grid.

For emission factors, we use the Emissions and Generation Resource Integrated Database (eGRID)—a comprehensive source of data on the environmental characteristics of almost all electric power generated in the US. Morgantown is located within the North American Electric Reliability Corporation's (NERC's) eastern Interconnect area and is a part of the Reliability First Corporation's western (RFCw) region (Figure 6).

Figure 6: eGRID sub-regions (2010)



Source: eGRID (2014).

2.1.1 *Activity-based emissions*

Electricity end-use emissions are calculated by multiplying the community's annual electricity use by the appropriate average annual electricity GHG emission factor. Electricity use data in total billed kilowatt-hour (kWh) for 2012 were provided by FirstEnergy for the Morgantown community. The data were broken down into commercial, residential, industrial, and street lighting categories. Independent electricity use data were collected for City operations and for WVU.

The regional average GHG emission factor for Morgantown was found within the latest version of the eGRID summary tables. The total output emission rates for CO_2, CH_4, and N_2O in the RFCw region were used as inputs. Equation 1 was used to calculate direct CO_2e emissions from electricity use.

Equation 1: Activity-based direct emissions from electricity consumption

$$Direct\ emissions\ = \frac{Electricity\ use\ \times EF}{2{,}204.6}$$

Source: ICLEI (2012b).

Where:

- Direct emissions = Direct emissions from electricity consumption (MT CO_2e/year)
- Electricity use = The community's electricity consumption from Table 2 (MWh/year)
- EF = Combined (CO_2, CH_4, N_2O) emission factor (1,511.52 pounds CO_2e/MWh)
- 2,204.6 = Conversion factor (pounds/MT)

Indirect emissions associated with transmission and distribution line loss range from 5.8-8.2% across all NERC regions. This electricity is lost to heat when electricity is transmitted through power lines. Line loss can vary depending on the location of the community and overall transmission distance to the end user (ICLEI, 2012b). Equation 2 was used to calculate CO_2e emissions from transmission and distribution.

Equation 2: Activity-based transmission and distribution emissions from electricity consumption

$$Transmission\ and\ distribution\ emissions\ = Direct\ emissions\ \times Grid\ loss\ factor$$

Source: ICLEI (2012b).

Where:

- Transmission and distribution emissions = Emissions from electricity generated but lost in transmission and distribution (MT CO_2e/year)
- Direct emissions = Result from Equation 1 (MT CO_2e/year)
- Grid loss factor = Average percent of electricity lost during transmission and distribution for the RFCw region (5.82%)

Upstream emissions associated with electricity production include emissions from energy consumed in order to extract, process, and deliver fuels to electricity generation facilities. The factors used to calculate upstream emissions from energy use combine the regional primary fuel mix, upstream primary fuel emissions, secondary fuel combustion emissions, and upstream secondary fuel emissions (ICLEI, 2012b). Equation 3 was used to calculate CO_2e emissions from upstream electricity production activities.

Equation 3: Activity-based upstream emissions from electricity consumption

$$Upstream\ emissions = \ Electricity\ use\ \times EF\ \times 0.001$$

Source: ICLEI (2012b).

Where:

- Upstream emissions = Upstream emissions from electricity consumption (MT CO_2e)
- Electricity use = Total electricity consumption, including transmission and distribution losses (kWh/year, not MWh/year)
- EF = Combined (CO_2, CH_4, and N_2O) regional upstream emission factor[2] (0.0688 kg CO_2e/kWh)
- 0.001 = Conversion factor (MT/kg)

Results are shown in Table 2 and Figure 7. The commercial sector consumed the largest amount of electricity and emitted the most GHG emissions in 2012, followed by the residential sector. The commercial sector, which includes WVU and City buildings, was the source of almost 80% of total GHG emissions from electricity use within the built environment in 2012. In total, across all sectors, 435,201 MWh of electricity was consumed and 347,434 MT CO_2e of GHG emissions was released in 2012.

End-use emissions from built environment electricity consumption represent close to 86% of total emissions. The remaining 14% are attributed to electricity lost in transmission and distribution and to upstream emissions.

The City street lighting included in Table 2 and Figure 7 represents only the City-owned and metered street lights. The remaining street lights, which are owned by Mon Power but are not metered, are not included in this inventory. The City is billed at a flat rate for the utility-owned street lights.

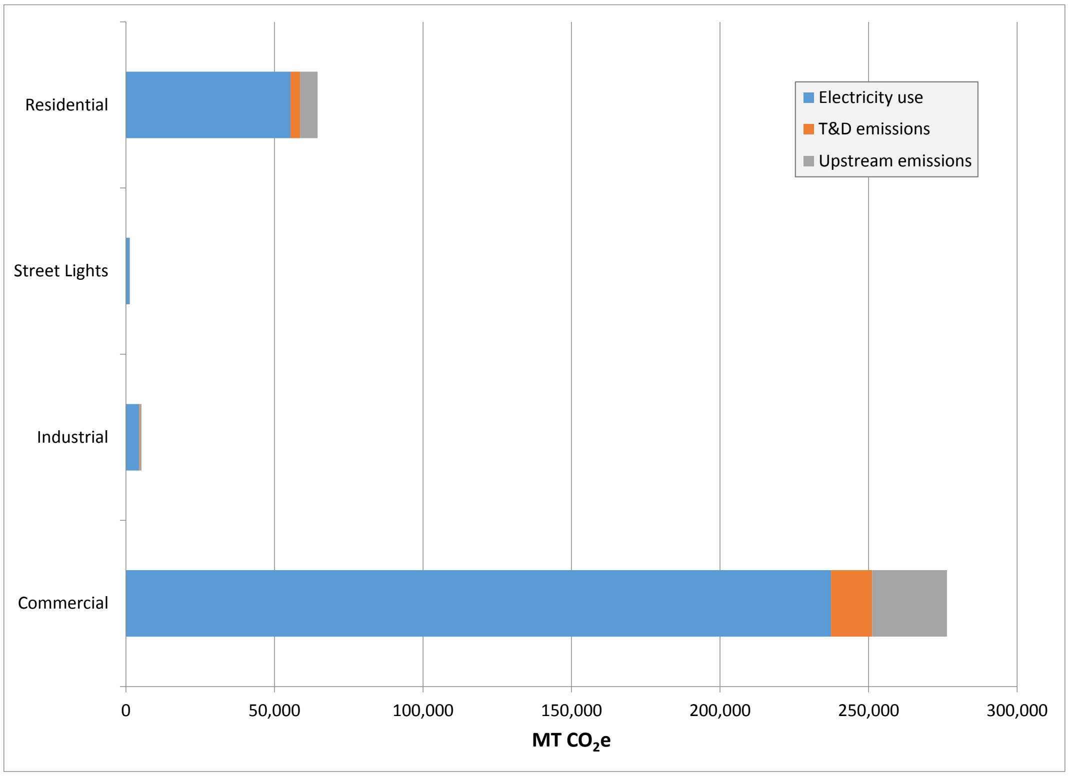
[2] The alternate upstream emissions factor for the NERC Eastern Interconnection Region were used.

Table 2: Electricity consumption and emissions results (2012)

Class	Electricity consumption (MWh)	Emissions ($MT\ CO_2e$)			
		End-use	Transmission and distribution	Upstream	Total
Commercial	346,216	237,374	13,815	25,206	**276,395**
Residential	80,800	55,398	3,224	5,883	**64,505**
Industrial	6,485	4,446	259	472	**5,177**
Street lights	1,700	1,166	68	124	**1,357**
Total	**435,201**	**298,384**	**17,366**	**31,684**	**347,434**

Source: Electricity consumption from Staggers (2013). Emissions calculated in this report. Note: Electricity consumption represents the amount billed to the customer. Electricity consumption associated with drinking water and wastewater treatment and distribution, provided separately by MUB, was subtracted from the Industrial class. Emissions associated with drinking water and wastewater treatment and distribution are calculated separately in Chapter 3.

Figure 7: Electricity emissions ($MT\ CO_2e$, 2012)



Source: Calculated in this report.

2.1.2 ***Source-based emissions***

The Morgantown Energy Facility, owned by Morgantown Energy Associates, is a fossil-fuel–fired cogeneration facility located on Beechurst Avenue within the city limits of Morgantown. The facility consists of two circulating fluidized bed boilers that burn coal and coal waste, along with related facilities, including a steam transmission line and two auxiliary natural-gas–fired boilers (WVDEP DAQ, 2013). The coal and coal waste boilers are the primary boilers. Occasionally, the natural gas boilers are used during times of maintenance or high steam demand from WVU. The facility has a gross capacity rating of 69 MW (Deloitte & Touche LLP, 2012). Normal operation is typically between 57 and 59 MW, with an export of 50 MW to the grid. The other 7-9 MW is attributed to internal use (WVDEP DAQ, 2013).

The Morgantown Energy Facility provides steam to WVU and to WVU Hospitals, Inc. under an agreement between Mon Power and the WVU Board of Regents that is set to expire in 2027 (Deloitte & Touche LLP, 2012). In 2012, the facility delivered 669,805 thousand pounds of steam under the WVU contract (Solomon, 2013).

According to the USEPA Mandatory Reporting Rule Database, the Morgantown Energy Facility emitted 613,298 MT CO_2e in 2012 (USEPA, 2013). This is the only power plant located within city limits.

Table 3 summarizes the source- and activity-based emissions associated with electricity use within the built environment in Morgantown. The Morgantown Energy Associates power plant produced a significant amount of emissions in 2012: 613,298 MT CO_2e. Activity-based emissions associated with electricity use within the built environment contributed 347,434 MT CO_2e. The largest portion of activity-based emissions, contributing 86%, is associated with end-use emissions, and the remaining 14% is associated with transmission and distribution losses as well as upstream emissions.

Table 3: Summary of emissions in the electricity sector (MT CO_2e, 2012)

Category	Emissions
Source-based	
Morgantown Energy Associates power plant	613,298
Total, source-based	**613,298**
Activity-based	
End-use emissions	298,384
Transmission and distribution emissions	17,366
Upstream emissions	31,684
Total, activity-based	**347,434**

Source: Calculated in this report.

2.2 Natural gas and other stationary fuels

Emissions associated with the built environment are also generated through the combustion of fuels used in residential and commercial stationary applications, such as natural gas used in boilers and furnaces, within city limits. Fuels used for production of electricity or district energy are excluded from this calculation because they are accounted for in Section 2.1 (ICLEI, 2012a).

End-use emissions associated with stationary combustion are considered to be both source- and activity-based because emissions occur at the point of combustion. Upstream emissions that occur during extraction, processing, and delivery of the fuel are activity-based only, because they occur outside city limits (Table 4).

Table 4: Types of source- versus activity-based emissions in the natural gas and other stationary fuels sector

Source-based emissions	Activity-based emissions
• End-use emissions from the use of natural gas, fuel oil/kerosene, and liquefied petroleum gas (LPG) in the city for space heating, hot water heating, and cooking	• End-use emissions from the use of natural gas, fuel oil/kerosene, and LPG in the city for space heating, hot water heating, and cooking • Upstream emissions associated with stationary fuels

"Stationary fuel combustion" is a broad category that covers activities that directly combust fuel for the production of heat used in a variety of end-use applications, including heating building spaces, providing process heat, and cooking (ICLEI, 2012b). While natural gas is the most widely used fuel in residential and commercial stationary applications and is the primary focus of this section, we also calculate emissions from bottled propane, kerosene, and fuel oil. Data are insufficient to calculate emissions associated with the use of coal or wood.

Combustion of natural gas and petroleum products for heating and cooking emits CO_2, CH_4, and N_2O. Across the US, emissions from natural gas consumption represent about 79% of the direct fossil fuel CO_2 emissions from residential and commercial sectors. Direct in-home coal consumption is a minor component of energy use in both of these sectors (USEPA, 2014e).

Dominion Hope, the local natural gas utility company, serves all of West Virginia and is a subsidiary company of Dominion. Dominion is one of the nation's largest producers and transporters of energy, with a portfolio of approximately 23,500 MW of generation capacity; 11,000 miles of natural gas transmission, gathering, and storage pipeline; and 6,400 miles of electric transmission. Dominion also operates one of the nation's largest natural gas storage systems, with 947 billion cubic feet of storage capacity, and serves retail energy customers in 15 states (Dominion, 2014a).

Dominion Hope is headquartered in Clarksburg, West Virginia, just south of Morgantown. It operates a 2,800-mile pipeline system within the state with 80 percent of the natural gas throughput sourced from Appalachia (Dominion, 2014b).

Natural gas is the most common stationary fuel used in residential and commercial applications in Morgantown. Dominion Hope provided end-use data for the residential, commercial, and industrial sectors that were used as inputs for these calculations. Equation 4 was used to calculate end-use emissions from stationary natural gas combustion. It was applied separately for the residential, commercial, and industrial sectors.

Equation 4: End-use emissions from stationary combustion of natural gas

$$End\ use\ emissions = Fuel\ use \times EF \times 0.001$$

Source: ICLEI (2012b).

Where:

- End-use emissions = End-use emissions from stationary combustion of natural gas (MT CO_2e/year)
- Fuel use = Natural gas consumption from Table 5 (Mcf/year)
- EF = Combined (CO_2, CH_4, N_2O) emission factor (54.64 kg CO_2e/Mcf)
- 0.001 = Conversion factor (MT/kg)

Data covering other stationary fuels were not available, but estimates were calculated, where possible, based on average use within the mid-Atlantic region. Equation 5 was used to calculate end-use emissions from other stationary fuels combusted in residential applications. The equation was applied separately for LPG and fuel oil and for the residential, commercial, and industrial sectors.

Equation 5: End-use emissions for stationary combustion of other fuels

$$End\ use\ emissions = No.\ households \times Per\ household\ energy\ use \times EF$$

Source: ICLEI (2012b).

Where:

- End-use emissions = Emissions from stationary combustion of other fuels (MT CO_2e/year)
- No. households = Number of households by fuel type from Table 7
- Per household energy use = Per-household energy use by fuel type from Table 7 (MMBtu/household/year)
- EF = Combined (CO_2, CH_4, N_2O) emission factor (0.0636 MT CO_2e/MMBtu for LPG, 0.0744 MT CO_2e/MMBtu for fuel oil)

Upstream emissions are associated with each stationary fuel combusted in the Morgantown community. Upstream emissions account for the leakage of primary fuels as well as emissions associated with secondary fuels that are used in the supply chain of the primary fuels. Equation 6 was used to calculate upstream emissions for the stationary fuels mentioned above. The equation was applied separately for natural gas, LPG, and fuel oil and for the residential, commercial, and industrial sectors.

Equation 6: Upstream emissions for stationary fuels

$$Upstream\ emissions = Fuel\ use \times EF \times 0.001$$

Source: ICLEI (2012b).

Where:

- Upstream emissions = Emissions from stationary fuels by upstream activities (MT CO_2e/year)
- Fuel use = Total fuel consumption from Table 5 for natural gas and Table 7 for other fuels (Mcf/year for natural gas; MMBtu/year for other fuels)
- EF = Combined (CO_2, CH_4, N_2O) emission factor (12.61 kg CO_2e/Mcf natural gas, 12.63 kg CO_2e/MMBtu LPG, 13.50 kg CO_2e/MMBtu fuel oil)
- 0.001 = Conversion factor (MT/kg)

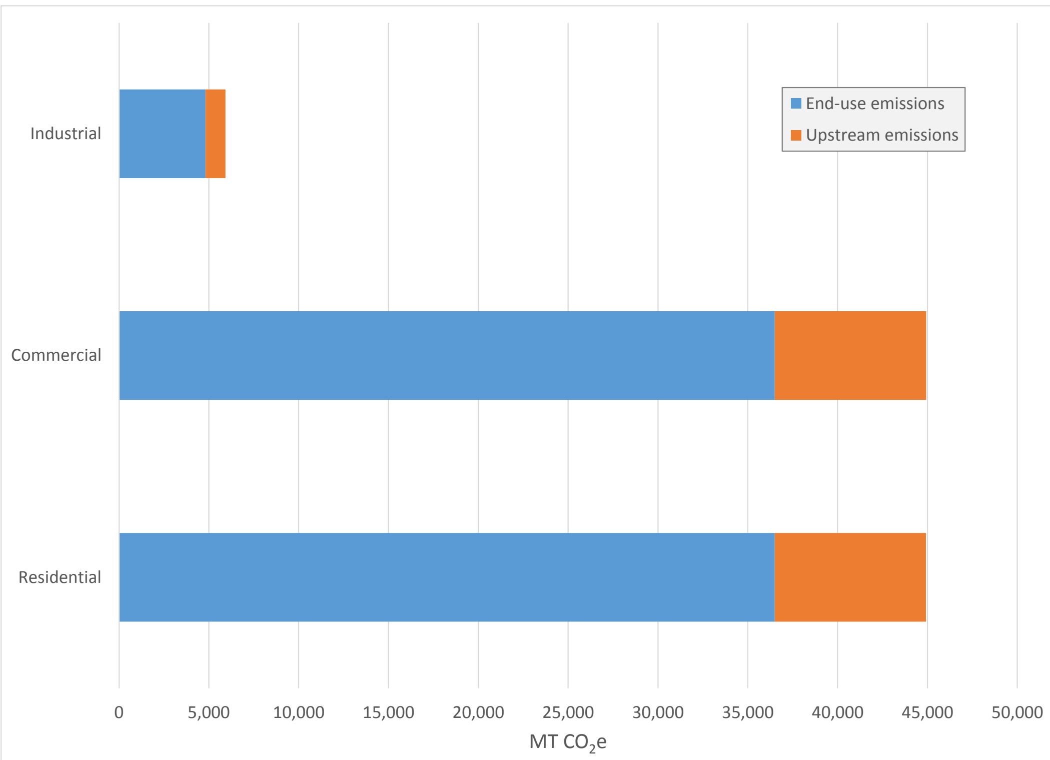
As shown in Table 5 and Figure 8, the volume of natural gas consumed in 2012 in the commercial and residential sectors was almost equal. Combined, these two sectors consumed just less than 94% of the total. The industrial sector consumed the remaining 6%.

Table 5: Natural gas consumption and emissions (activity- and source-based, 2012)

Sector	Natural gas consumption (Mcf)	Emissions (MT CO_2e)		
		End-use	Upstream	Total
Commercial	668,175	36,506	8,423	**44,930**
Residential	668,061	36,500	8,422	**44,922**
Industrial	88,119	4,814	1,111	**5,925**
Total	**1,424,355**	**77,821**	**17,956**	**95,777**

Source: Calculated in this report.

Figure 8: Natural gas emissions (MT CO_2e, 2012)



Source: Calculated in this report.

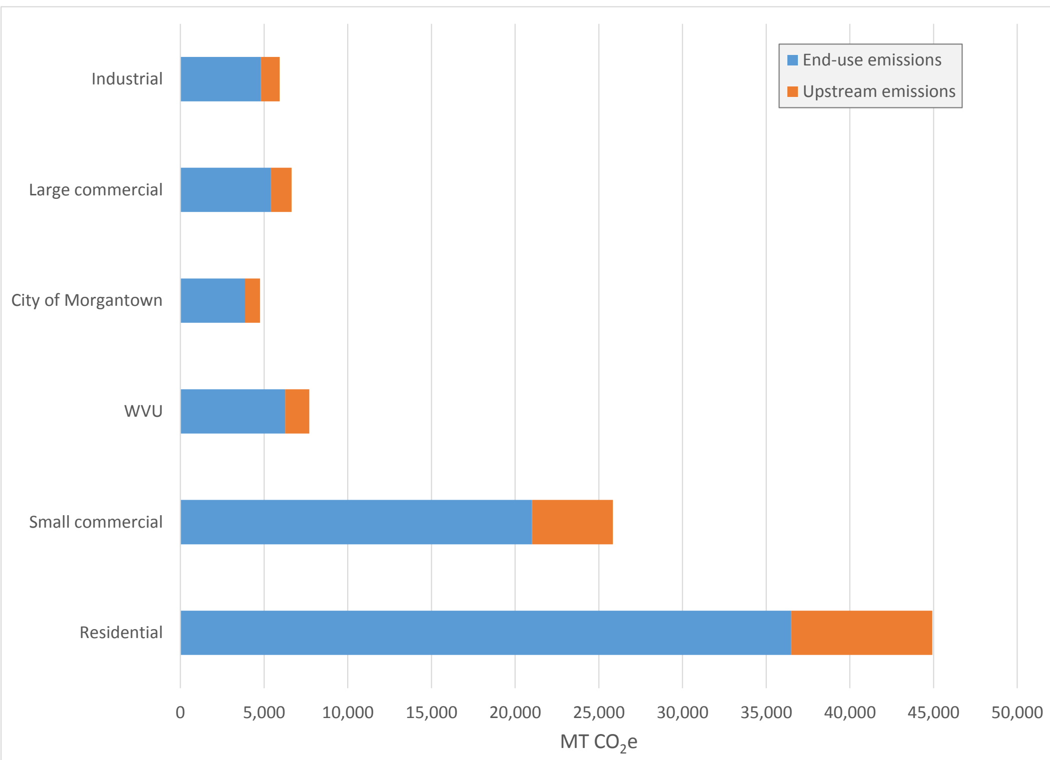
Table 6 and Figure 9 provide more detailed breakdowns of natural gas consumption and emissions. The small commercial class is by far the largest consumer of natural gas within the commercial sector. Emissions from the small commercial class represent almost 58% of the total within the commercial sector. The small commercial class is defined as businesses that consume between less than 10,000 Mcf over a 12-month period (Morris, 2014a). WVU, across its 186 accounts, is the second-largest user of natural gas in the commercial sector, followed by the large commercial class and the City.

Table 6: Detailed natural gas consumption and emissions (2012)

Customer class	Natural gas consumption (Mcf)	Accounts	Emissions ($MT\ CO_2e$) End-use	Upstream	Total
Residential	**668,061**	**12,557**	**36,500**	**8,422**	**44,922**
Commercial					
Small commercial	384,263	989	20,995	4,844	25,839
WVU	114,540	186	6,258	1,444	7,702
Large commercial	98,729	7	5,394	1,245	6,639
City of Morgantown	70,644	19	3,860	891	4,750
Subtotal, commercial	**668,175**	**1,201**	**36,506**	**8,423**	**44,930**
Industrial	**88,119**	**3**	**4,814**	**1,111**	**5,925**
Total	**1,424,355**	**13,761**	**77,821**	**17,956**	**95,777**

Source: Calculated in this report. Note: Subtotals may not match due to rounding.

Figure 9: Detailed natural gas emissions ($MT\ CO_2e$, 2012)



Source: Calculated in this report.

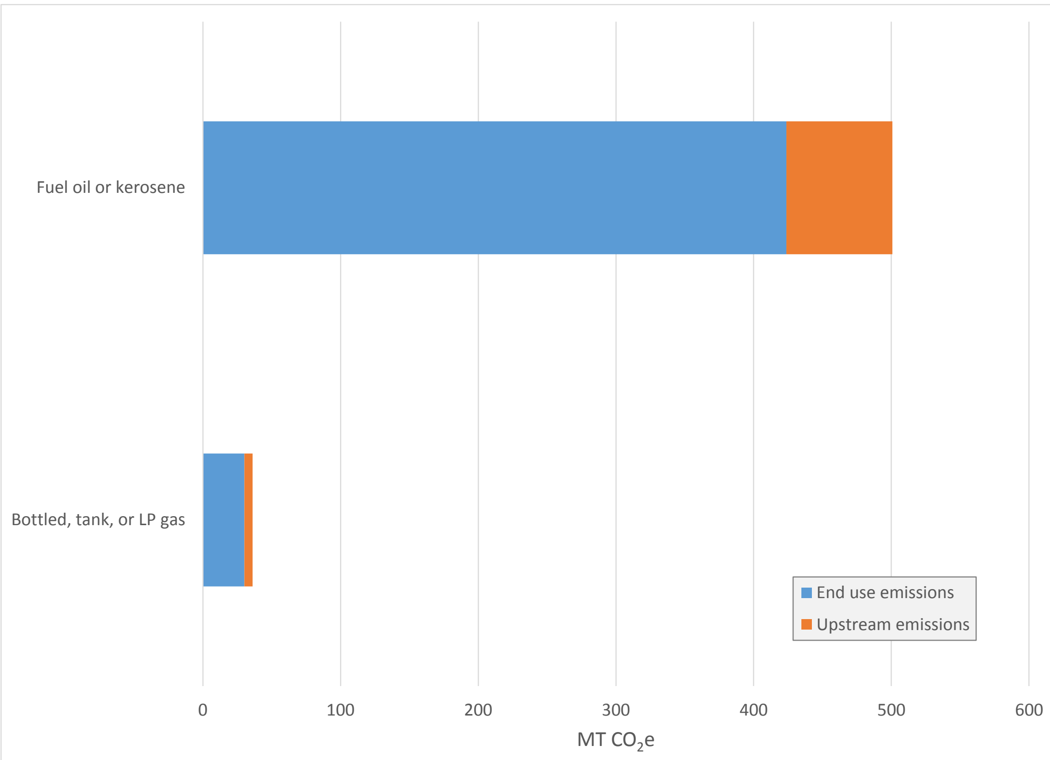
GHG emissions associated with other stationary fuels, as detailed in Table 7 and Figure 10, are much lower than the emissions associated with natural gas. Households using LPG or fuel oil within Morgantown represent less than 2% of the 6,626 total units characterized in the American Community Survey (US Census Bureau, 2012). Other stationary fuels only add an additional 537 MT CO_2e, compared to the 44,922 MT CO_2e emitted from natural gas use in the residential sector. Per MMBtu combusted in household applications, LPG produces a smaller amount of CO_2e than fuel oil.

Table 7: Consumption and emissions for other residential fuels (2012)

Fuel	House-holds	Percent of occupied units	MMBtu/ HH/year	Total MMBtu/ year	Emissions ($MT\ CO_2e$)		
					End-use	Upstream	Total
Bottled, tank, or LPG	73	0.71%	6.5	475	30	6	**36**
Fuel oil or kerosene	128	1.25%	44.5	5,696	424	77	**501**

Source: Households and percent of occupied households from US Census Bureau (2012). MMBtu/household/year from Energy Information Administration (2013b). Total MMBtu/year and emissions calculated in this report.

Figure 10: Emissions for other residential fuels ($MT\ CO_2e$, 2012)



Source: Calculated in this report.

Table 8 summarizes source- and activity-based emissions associated with stationary fuels within the built environment. Both the source- and activity-based emissions include end-use emissions; however, the activity-based emissions also include upstream emissions.

Natural gas is the most widely used stationary fuel in the residential and commercial sectors in Morgantown. LPG and fuel oil make up less than 1% of total source-based emissions. Source-based emissions from stationary fuel combustion produced 78,275 $MT\ CO_2e$ in 2012.

Similar to the source-based category, emissions from natural gas combustion make up approximately 99% of activity-based GHG emissions from stationary fuels within the built environment. Activity-based emissions from stationary fuel combustion produced 96,314 $MT\ CO_2e$ in 2012.

Table 8: Summary of emissions in the natural gas and other stationary fuels sector (MT CO_2e, 2012)

Category	Emissions
Source-based	
Natural gas, end-use	77,821
Other fuels, end-use	454
Total, source-based	**78,275**
Activity-based	
Natural gas	
End-use	77,821
Upstream	17,956
Subtotal	**95,777**
Other fuels	
End-use	454
Upstream	83
Subtotal	**537**
Total, activity-based	**96,314**

Source: Calculated in this report.

3. DRINKING WATER AND WASTEWATER

Morgantown Utility Board (MUB) is a municipally owned water utility that provides drinking water and wastewater services to Morgantown and many other Monongalia County communities. MUB's water treatment facility is located along Don Knotts Boulevard within the city limits, and its primary wastewater treatment facility is just beyond the city limits in Star City. All wastewater generated in the city of Morgantown is fed into the Star City wastewater treatment plant.[3]

The drinking water and wastewater sectors use electricity to treat and distribute water and wastewater throughout the greater Morgantown area. Additional GHGs are emitted from the treatment of wastewater; however, there are no direct emissions from the drinking water treatment process.

3.1 Drinking water

GHG emissions generated through the production of drinking water for residents and businesses are dependent on the source of water, distances and topography encountered in water distribution, and treatment processes used. The main source of drinking water for the Morgantown area is the Monongahela River, which supplies 90.5 percent of the area's drinking water. The remaining 9.5 percent of MUB's raw water supply is drawn from the Cobun Creek Reservoir (MUB, 2014). After treatment, the water is distributed throughout the city and much of the surrounding county.[4]

Emissions associated with drinking water are considered to be activity-based because most power plants that generate the electricity that powers the treatment plant and booster stations are located beyond the city limits.

Importantly, the water treatment facility treats and distributes water for customers both within and outside of the Morgantown city limits. Therefore, GHG emissions associated with drinking water treatment and distribution reflect activities from within and outside of the Morgantown community. For the Morgantown GHG inventory, total emissions associated with the plant must be scaled down.

To differentiate between total emissions and those properly assigned to Morgantown residents, businesses, and WVU, we start by calculating emissions for all electricity used by the water treatment plant and booster stations within the city limits. We then calculate activity-based emissions for the Morgantown community by applying a percentage that reflects the Morgantown community's share of total emissions (Table 9).

Table 9: Source- versus activity-based emissions associated with the drinking water sector

Source-based emissions	Activity-based emissions
• No source-based emissions calculated for drinking water because the emissions are associated with electricity use that is generated outside of the city limits	• A share of emissions from electricity usage for booster stations located in the city • A share of emissions from electricity for the drinking water treatment plant

[3] MUB operates a second wastewater facility in Cheat Lake, though the service area for this facility does not fall within the Morgantown city limits. This facility is therefore not included in this report.

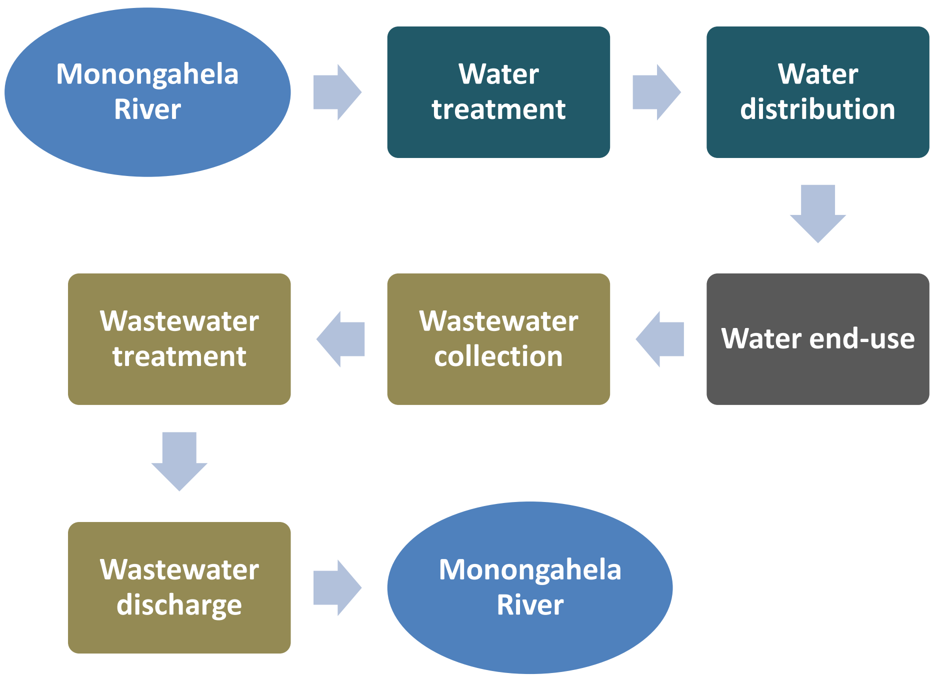
[4] Any electricity used at residences or commercial buildings for final dispersal of water is omitted from this section and is instead captured in Section 2.1.1.

Figure 11 illustrates the energy-consuming processes in the delivery and treatment of drinking water and wastewater. Energy-consuming processes for drinking water include:

- **Water treatment**, which includes pumps and equipment that convey raw water from the Monongahela River to the treatment facility and that treat the raw water.
- **Water distribution**, which includes the pumps in booster stations that distribute and pressurize clean drinking water in the local distribution system.

Emissions from water treatment and distribution are summed to calculate the total GHG emissions associated with drinking water electricity use.

Figure 11: Process for delivery and treatment of drinking water and wastewater



3.1.1 *Treatment*

Within the water treatment category, we consider electricity used for water supply, conveyance, and treatment. Water supply is the process of pulling raw water from the Monongahela River,[5] water conveyance is the process of moving water from the intake to the plant, and water treatment is the process of treating the raw water. Electricity data for 2012 were provided by MUB (Wright, 2013). Electricity usage and water quantity data were provided by month for the water treatment facility and for all MUB-operated booster stations. Monthly totals that included electricity usage for water supply, conveyance, and treatment were reported by MUB and therefore could not be broken down separately by individual category.

GHG emissions associated with the water treatment plant and booster stations were derived using methods described in Section 2.1.1. These emissions include direct emissions from electricity consumption (Equation 1), transmission and distribution emissions (Equation 2), and upstream emissions (Equation 3).

[5] Electricity is not required to draw water from the Cobun Creek Reservoir because it is gravity-fed to the treatment plant.

Table 10 shows the per-month electricity usage and GHG emissions associated with water treatment within the city of Morgantown. As previously mentioned, these numbers reflect electricity usage and emissions associated with treating water for MUB customers both within and outside of Morgantown.

Table 10: Electricity use and emissions for Morgantown Utility Board's water treatment plant (2012)

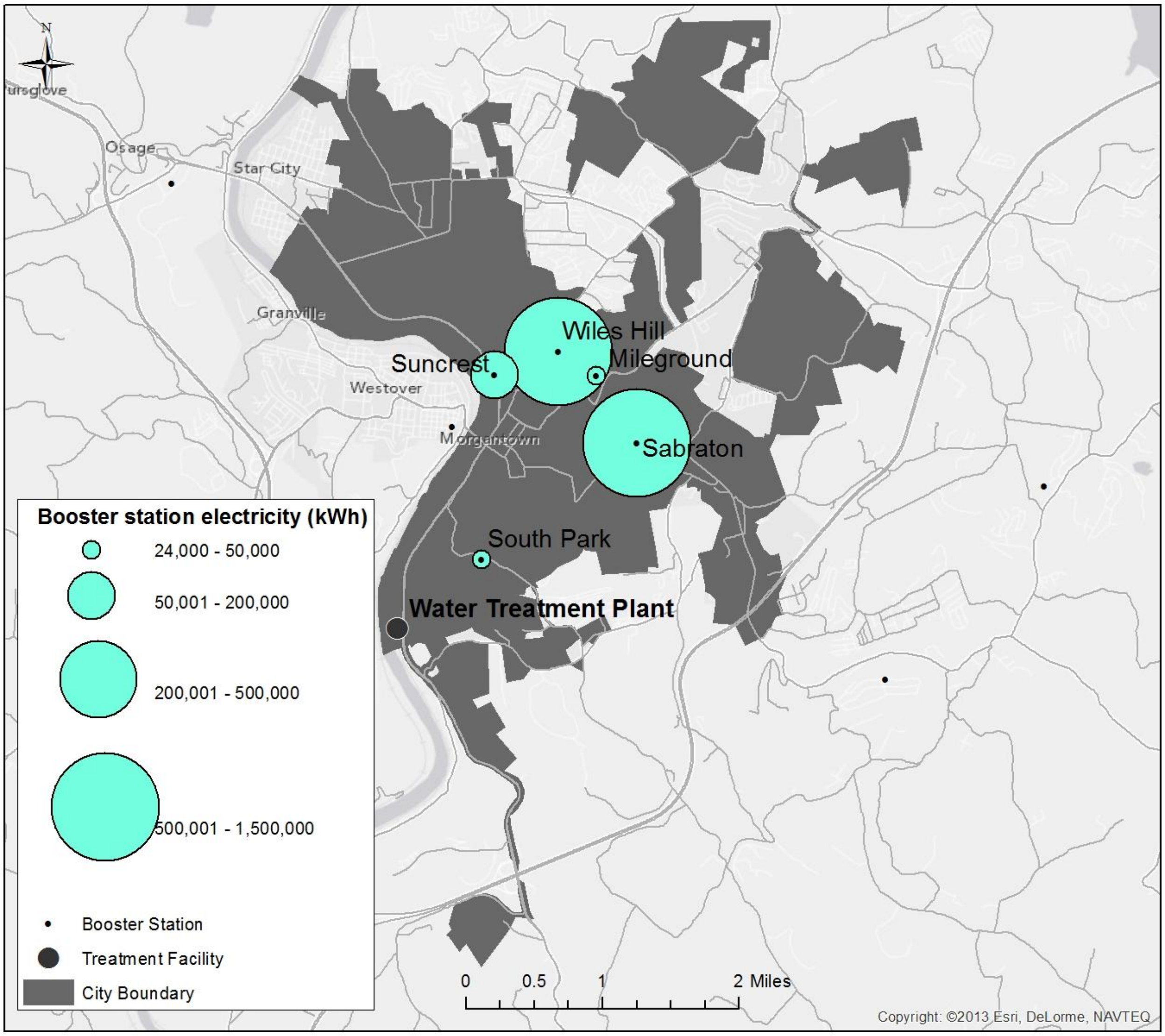
Month	Electricity use (kWh)	Emissions (MT CO_2e)
January	637,068	509
February	616,109	492
March	624,398	498
April	628,654	502
May	656,371	524
June	626,962	501
July	685,693	547
August	718,790	574
September	672,675	537
October	769,902	615
November	667,626	533
December	672,955	537
Total	**7,977,203**	**6,368**

Source: Electricity use from Wright (2013). Emissions calculated in this report.

3.1.2 *Distribution*

Monthly electricity usage data were provided by MUB for all booster stations within and outside of Morgantown's city limits; however, only the electricity usage at booster stations within the city of Morgantown was used to determine GHG emissions associated with water distribution (Table 11). Methods described in Section 2.1.1 were used to calculate emissions and include direct, transmission and distribution, and upstream emissions. Figure 12 maps electricity use for booster stations within city limits.

Figure 12: Electricity used by booster stations within the city of Morgantown



Source: Emissions calculated in this report.

Table 11: Monthly electricity use and emissions for Morgantown booster stations (2012)

Month	Mileground	Sabraton	Suncrest	South Park	Wiles Hill	Total	Total emissions (MT CO_2e)
Electricity use (kWh)							
January	2,538	38,560	15,200	2,366	108,120	166,784	**133**
February	2,150	41,280	13,440	1,680	92,880	151,430	**121**
March	1,641	38,400	13,280	3,637	87,720	144,678	**116**
April	2,008	38,080	11,840	3,425	73,680	129,033	**103**
May	2,170	41,760	12,480	3,563	75,600	135,573	**108**
June	2,075	50,880	16,160	4,098	94,920	168,133	**134**
July	1,945	46,400	15,360	4,098	106,320	174,123	**139**
August	1,979	50,240	15,680	2,744	100,800	171,443	**137**
September	2,243	45,760	15,360	3,581	126,960	193,904	**155**
October	2,133	43,200	14,400	4,058	96,120	159,911	**128**
November	2,196	51,520	13,440	3,581	86,400	157,137	**125**
December	1,625	38,400	12,320	3,766	77,160	133,271	**106**
Total	**24,703**	**524,480**	**168,960**	**40,597**	**1,126,680**	**1,885,420**	**1,505**
Emissions (MT CO_2e)							
Total	**20**	**419**	**135**	**32**	**900**	**N/A**	**1,505**

Source: Electricity use from Wright (2013). Emissions calculated in this report.

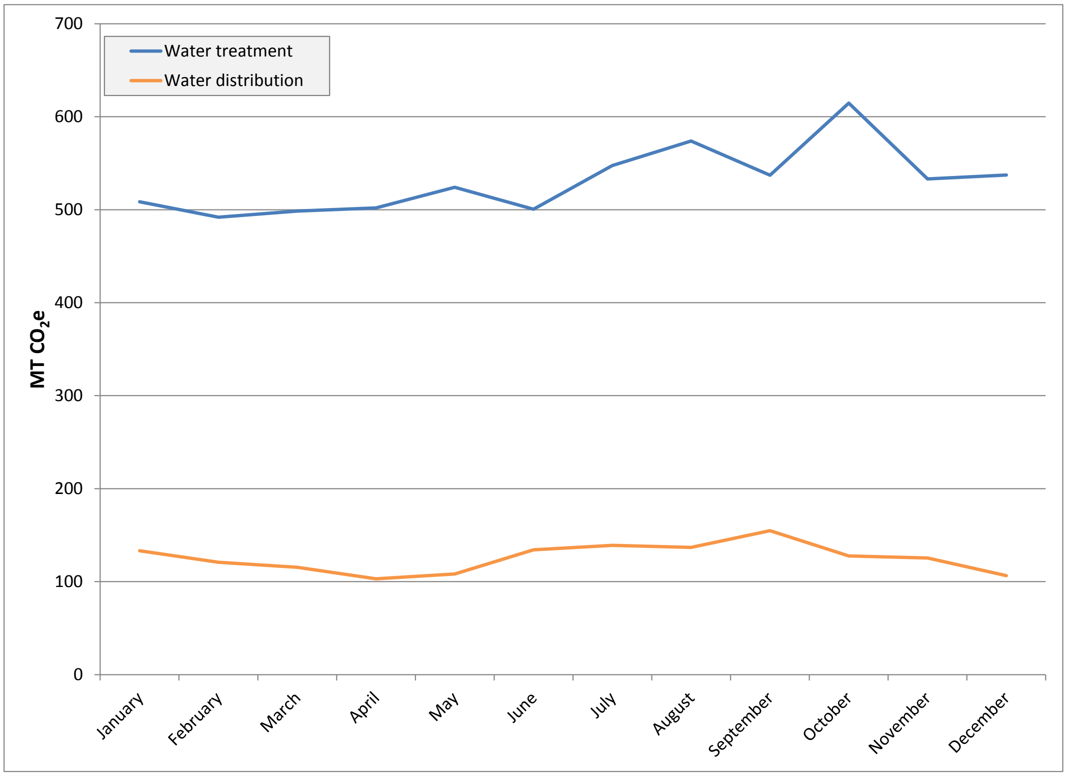
A noticeable increase in electricity usage can be observed for the summer and fall months. This increase is likely due to hotter temperatures and increased water consumption (Table 11). Spring months experience the lowest energy use and emissions.

The Wiles Hill and Sabraton booster stations generated substantially more emissions than the others. This was likely due to topography, number of customers served, and distance from the water treatment plant (Table 11). The Wiles Hill booster station distributes water up steep topography from downtown Morgantown, providing service to a large number of customers.

3.1.3 *Total*

Water treatment emissions for the year 2012 (6,368 MT CO_2e) were over four times higher than water distribution emissions (1,505 MT CO_2e). The monthly emissions pattern was relatively consistent across both treatment and distribution, with an increase in emissions in the summer and fall months (Figure 13). Emissions from drinking water treatment and distributions totaled 7,874 MT CO_2e in 2012.

Figure 13: Total drinking water treatment and distribution emissions per month (MT CO_2e, 2012)



Source: Emissions calculated in this report.

Table 12: Total drinking water emissions (MT CO_2e, 2012)

Type	Treatment	Distribution	Total
Total	6,368	1,505	**7,874**

Source: Calculated in this report.

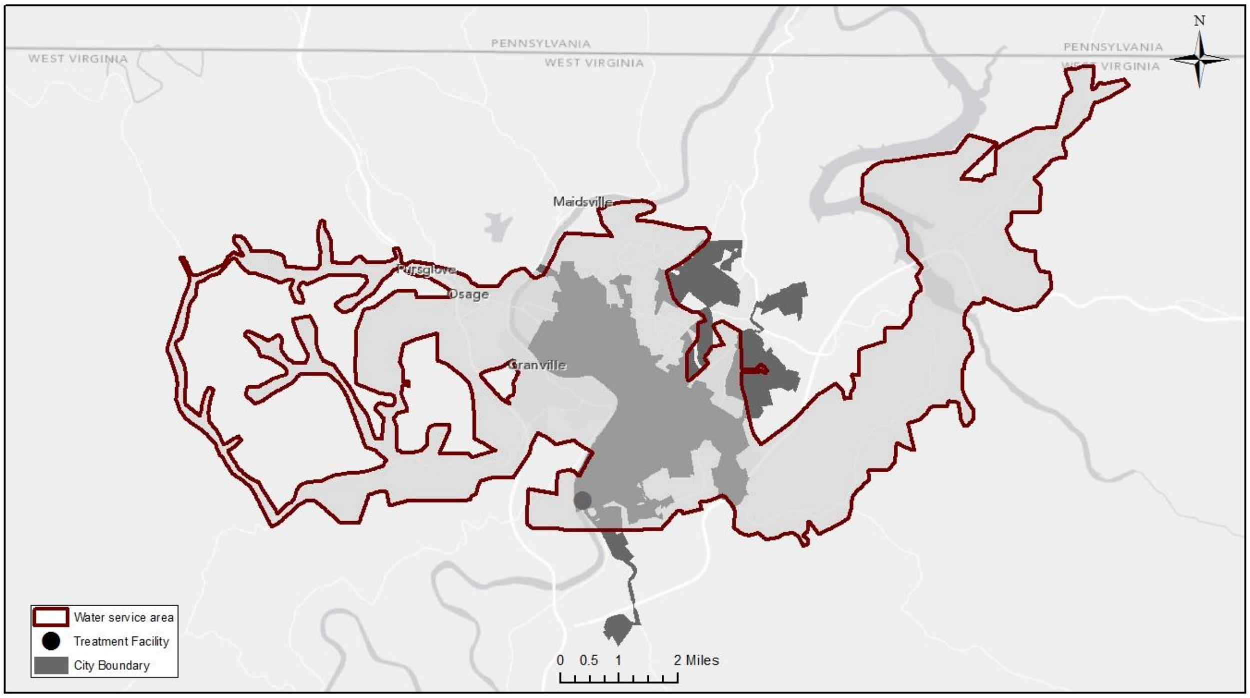
Because the drinking water treatment plant and associated facilities provide water to users within and beyond the Morgantown city limits, the electricity use associated with the Morgantown community is actually a subset of the total electricity usage reported by MUB.

To estimate the proportion of electricity use associated with activities within the city limits, we first identified the total number of water users serviced through MUB. The Public Service Commission (PSC) identified 24,509 average MUB customers (PSC, 2013). Because there are typically multiple water users for each customer, it was necessary to estimate the number of users within the water service area. We therefore identified the total population within the water service area by intersecting a water service area boundary for the MUB water treatment plant (Figure 14), which was provided by MUB, with 2010 census block-level data. Using this approach, the total population within the water service area was estimated to be 71,002.

We then divided the total Morgantown population in 2012 (31,000) by the total service area population (71,002) and used this proportion to estimate the proportion of electricity use to assign to the Morgantown community. It is important to note that this 44% proportion is likely a conservative estimate given that many water use activities within the city limits would not be captured by census population information alone. For example, daytime and/or seasonal students at WVU would not typically be accounted for in the census population estimates. Daytime workers and commuters that reside outside of the city limits yet use water through activities within the city limits are also not accounted for in census data.

MUB did not provide information detailing WVU's water usage activities, nor did they provide information characterizing daytime users or industrial/commercial users. Because of the complexities and required assumptions in estimating all water usage activities within the city limits, the official city population was used to characterize the proportion of water usage activity within the city. We estimate that the actual activity-based emissions associated with drinking water treatment and distribution would likely be at least 50% higher if WVU students and daytime commuters were included.

Figure 14: Morgantown Utility Board water service area



The activity-based water treatment GHG emissions for the Morgantown community are calculated as 44% of the water treatment plant's total emissions (Table 13). Treatment emissions make up 80% of the total emissions, with distribution making up the remaining 20%.

Table 13: Total activity-based drinking water emissions (MT CO_2e, 2012)

Type	Treatment	Distribution	Total
Total	2,802	662	3,464

Source: Calculated in this report.

3.2 Wastewater

Wastewater management generates GHG emissions through the use of electricity for the collection, treatment, and discharge of wastewater. GHG emissions are also generated via the treatment process itself.

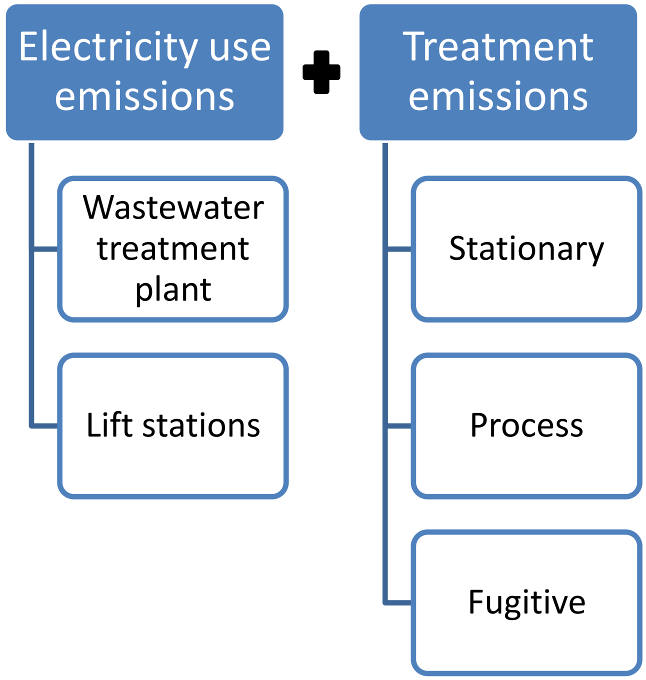
Wastewater from the city of Morgantown is serviced by the wastewater treatment plant in Star City. The plant also treats wastewater from communities outside of the city limits. The wastewater treatment plant is a conventional treatment operation that uses biological processes, including activated sludge and a rotating biological contactor. Figure 11, above, illustrates the energy-consuming processes in the collection and treatment of wastewater.

- **Wastewater collection** includes the pumps used to move wastewater to the treatment facility. Most wastewater collection is gravity-fed, but lift station pumps are used when elevation gain is needed.
- **Wastewater treatment** includes the pumps within the wastewater treatment plant, plus the operation of treatment equipment such as blowers, mixers, mechanical dewatering, and digestion equipment.
- **Wastewater discharge** includes the pumps used to convey treated wastewater back to the Monongahela River.

The electricity used throughout these processes produces GHG emissions. It is important to note that the electricity used to power the lift stations, and their associated emissions, are not captured in the built environment analysis (Table 2). We calculate lift station electricity and emissions in this section in order to comply with the Community Protocol, which suggests that the drinking water and wastewater sector be fully characterized.

In addition to GHGs generated via electricity use, the plant itself creates stationary, process, and fugitive GHG emissions. CO_2, CH_4, and N_2O are produced at different phases during the wastewater treatment process (Figure 15). Stationary emissions are generated through the anaerobic digestion of biosolids and combustion of digester gas at the wastewater treatment plant. Process emissions of N_2O are generated when treatment plants employ processes such as nitrification/denitrification or aeration basins. CH_4 is produced when microorganisms degrade soluble organic material in wastewater, which can potentially be released into the environment during collection and treatment. N_2O is produced when treating wastewater to remove excess nitrogen. Wastewater discharged into the Monongahela River also contain small amounts of nitrogen discharged into natural waters, which may also be released as N_2O.

Figure 15: Activity-based emissions from wastewater collection, treatment, and distribution



As with the drinking water emissions, we start by calculating total emissions for lift stations within the city limits and for the wastewater treatment plant itself (Table 14).

Table 14: Source- and activity-based emissions from the wastewater treatment sector

Source-based emissions	Activity-based emissions
• No source-based emissions calculated for wastewater because the emissions are associated with electricity use that is generated outside of the city limits	• A share of emissions from electricity usage for wastewater lift stations located in the city • A share of emissions from electricity usage at the wastewater treatment plant • A share of stationary, process, and fugitive emissions at the wastewater treatment plant

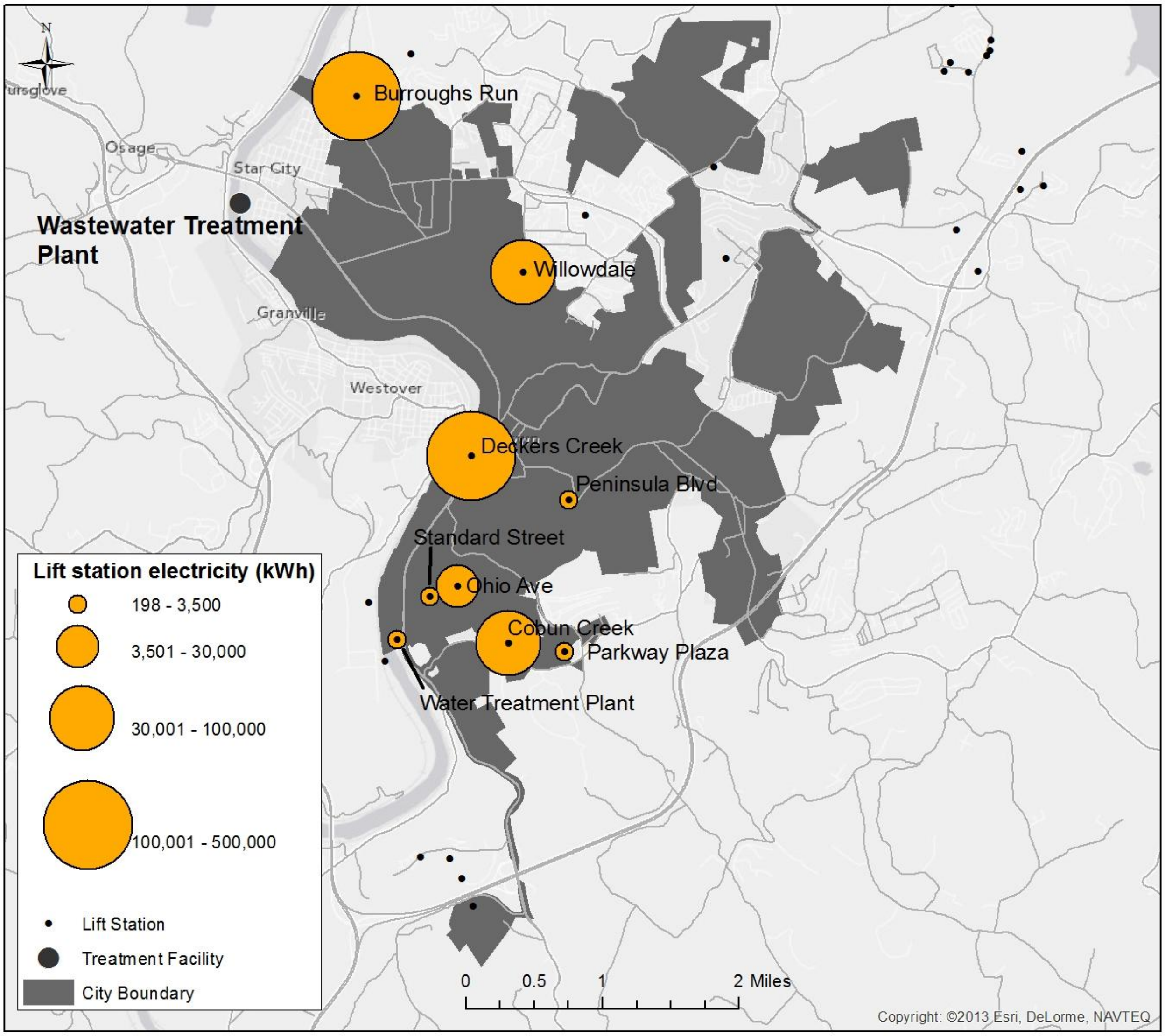
3.2.1 *Electricity use*

The first calculation step is to calculate GHG emissions associated with the lift stations and the wastewater treatment plant. We then scale these emissions down to calculate the emissions attributed to the Morgantown community.

Emissions associated with wastewater are considered to be activity-based because most power plants that generate the electricity that powers the treatment plant and lift stations are located beyond the city limits.

Lift stations are the only wastewater facilities within the city of Morgantown because the water treatment and discharge infrastructure is located in Star City (Figure 16). Wastewater is primarily transported by gravity through sewer pipes. However, electricity is also used for wastewater collection and transport; when elevation gain is required, lift stations are employed. Monthly electricity usage and wastewater quantity data for 2012 were provided by MUB for all lift stations (Wright, 2013).

Figure 16: Electricity used by wastewater lift stations within the city of Morgantown



Source: Calculated in this report.

Methods described in Section 2.1.1 were used to calculate emissions based on lift station electricity use. These emissions include direct, transmission and distribution, and upstream emissions.

Wastewater electricity use in the city of Morgantown was highest in winter and lowest in the summer (Table 15). The Deckers Creek and Burroughs Run lift stations consumed the most energy, while the Willowdale and Peninsula Boulevard lift stations consumed the least (Table 16).

Table 15: Electricity use and emissions for Morgantown lift stations (by month, 2012)

Month	Electricity use (kWh)	Emissions (MT CO_2e)
January	99,367	79
February	92,875	74
March	68,062	54
April	57,487	46
May	72,226	58
June	60,719	48
July	53,698	43
August	50,557	40
September	54,968	44
October	52,139	42
November	82,896	66
December	83,669	67
Total	**828,663**	**662**

Source: Electricity use from MUB (2012). Emissions calculated in this report.

Table 16: Electricity use and emissions for Morgantown lift stations (by lift station, 2012)

Lift station	Electricity use (kWh)	Emissions (MT CO_2e)
Burroughs Run	280,320	224
Cobun Creek	91,202	73
Deckers Creek	395,712	316
Ohio Ave	998	1
Parkway Plaza	3,349	3
Peninsula Blvd	198	<1
Standard Street	24,807	20
Willowdale	546	<1
Water treatment plant	31,531	25
Total	**828,663**	**662**

Source: Electricity use from Wright (2013). Emissions calculated in this report. Note: The water treatment plant also houses a wastewater lift station

MUB was unable to provide specific estimates detailing the proportion of wastewater generated by customers from within and outside the city of Morgantown. The PSC estimated the average number of sewer customers at 19,069 for the year 2012 (PSC, 2013). Similar to the water treatment emissions methods in Section 3.1, this number does not reflect the actual contributing wastewater population, nor the quantity of wastewater contribution per customer, given that there can be multiple people per customer and varying amounts of wastewater generated per customer.

MUB did not delineate the service area for the wastewater treatment plant, so we were unable to use similar census-based methods as outlined in the water treatment inventory to estimate the percentage of wastewater customers that are within the Morgantown community. Due to this lack of information, we assumed that 80% of the wastewater treatment plant electricity use was attributed to the city of Morgantown after MUB staff stated that “a good majority” of wastewater was from the City of Morgantown (Shellito, 2014).

MUB did not provide data detailing which lift stations carried city-based wastewater, and which ones did not. We therefore assumed that activity-based electricity use of the lift stations was limited to lift stations within the city limits, and that 80% of the total electricity per lift station was attributed to the Morgantown community.

Methods described in Section 2.1.1 were used to calculate emissions based on wastewater treatment plant electricity use. These emissions include direct, transmission and distribution, and upstream emissions.

Table 17: Wastewater treatment plant electricity use and electricity-based emissions (2012)

Month	Electricity use (kWh)	Emissions (MT CO_2e)
January	308,310	246
February	313,291	250
March	261,314	209
April	275,104	220
May	266,391	213
June	285,366	228
July	247,746	198
August	299,485	239
September	269,511	215
October	332,639	266
November	317,797	254
December	281,333	225
Total	**3,458,287**	**2,761**

Source: Electricity use from Wright (2013). Emissions calculated in this report.

Monthly emissions from the wastewater treatment plant were relatively consistent for the year, with the highest emissions occurring in October and the lowest occurring in July (Table 17). As described above, 80 percent of emissions from lift stations (Table 16) and the treatment plant (Table 17) were attributed to the Morgantown community, totaling 2,738 MT CO_2e (Table 18). In 2012, the water treatment plant emitted over four times the greenhouses gases as all lift stations within the city of Morgantown.

Table 18: Activity-based wastewater treatment plant emissions (MT CO_2e, 2012)

	Emissions
Water treatment plant	2,209
Lift stations	529
Total	**2,738**

Source: Calculated in this report.

3.2.2 *Treatment process*

The treatment process itself generates GHGs in addition to those generated through the use of electricity. Process emissions are calculated per person; therefore, the 80% estimate used to apportion electricity-based GHGs to the Morgantown community is not needed. Instead, process emissions are based on Morgantown's population of 31,000. Similar to the water treatment emissions in Section 3.1, this population estimate is conservative given the wastewater contributions from students and non-resident workers.

Stationary CH_4 emissions are generated from devices designed to combust gas produced by a centralized wastewater treatment plant that uses anaerobic digesters. Equation 7 was used to estimate 2012 stationary CH_4 emissions.

Equation 7: CH_4 emissions from combustion of gas at the wastewater treatment plant

$$CH_4\ emissions = P \times Digester\ gas \times fCH_4 \times BTU_{CH4} \times 10^{-6} \times EF_{CH4} \times 365.25 \times 10^{-3} \times GWP_{CH4}$$

Source: ICLEI (2012c).

Where:

- CH_4 emissions = Total CH_4 emitted by devices designed to combust digester gas (MT CO_2e/year)
- P = Population served by the wastewater treatment plant (31,000)
- Digester gas = Volume of digester gas produced per person per day (1 $foot^3$/person/day)
- fCH_4 = Fraction of CH_4 in gas (0.65)
- BTU_{CH4} = Default energy content of CH_4, higher heating value (1,028 Btu/$foot^3$ CH_4)
- 10^{-6} = Conversion (MMBtu/Btu)
- EF_{CH4} = CH_4 emission factor (0.0032 kg CH_4/MMBtu)
- 365.25 = Conversion factor (days/year)
- 10^{-3} = Conversion factor (MT/kg)
- GWP_{CH4} = Global warming potential (21 MT CO_2e/MT CH_4)

Process N_2O emissions are generated by wastewater treatment plants that do not support transient or complete nitrification or denitrification. Equation 8 was used to estimate 2012 process N_2O emissions.

Equation 8: N_2O emissions from the wastewater treatment plant

$$N_2O\ emissions = P \times F_{ind-com} \times EF \times 10^{-6} \times GWP_{N2O}$$

Source: ICLEI (2012c).

Where:

- N_2O emissions = Total annual N_2O emitted by the wastewater treatment plant (MT CO_2e/year)
- P = Population served by the wastewater treatment plant (31,000)
- $F_{ind-com}$ = Factor for high nitrogen loading of industrial or commercial discharge. The wastewater treatment plant treats wastewater from industrial and commercial sources (1.25)
- EF = Emission factor for a wastewater treatment plant without nitrification or denitrification (3.2 grams N_2O/person-equivalent/year)
- 10^{-6} = Conversion factor (MT/gram)
- GWP_{N2O} = Global warming potential (310 MT CO_2e/MT N_20)

Treated wastewater effluent is discharged to the Monongahela River. Wastewater treatment plants are not able to remove all of the nitrogen content in wastewater, and N_2O is only present in trace amounts of effluent. When effluent containing nitrogen reaches the Monongahela River, indirect N_2O emissions ("fugitive emissions") occur through side reactions. Equation 9 was used to estimate 2012 fugitive N_2O emissions.

Equation 9: N_2O emissions from treated wastewater effluent

$$N_2O\ emissions = [P \times F_{ind-com} \times (Total\ N\ load - N\ uptake \times BOD_5\ load) \times EF\ effluent \times (44 \div 28) \times (1 - Fplant) \times 365.25 \times 10^{-3}] \times GWP_{N2O}$$

Source: ICLEI (2012c).

Where:

- N_2O emissions = Total annual N_2O emitted by treated wastewater effluent discharged into the Monongahela River (MT CO_2e/year)
- P = Population served by the wastewater treatment plant (31,000)
- $F_{ind\text{-}com}$ = Factor for industrial or commercial discharge. The wastewater treatment plant treats wastewater from industrial and commercial sources (1.25)
- Total N load = Average total nitrogen per day (0.026 kg N/person/day)
- N uptake = Nitrogen uptake for cell growth in aerobic systems (0.05 kg N/kg BOD_5)
- BOD_5 load = Amount of BOD_5 produced per person per day (0.09 kg BOD_5/person/day)
- EF effluent = Emission factor (0.005 kg N_2O-N/kg sewage-N discharged)
- 44/28 = Molecular weight ratio of N_2O to N_2
- Fplant = Fraction of nitrogen removed from the plant without nitrification/denitrification (0)
- 365.25 = Conversion factor (days/year)
- 10^{-3} = Conversion (MT/kg)
- GWP = Global warming potential (310 MT CO_2e/MT N_2O)

As shown in Table 19, 95% of activity-based emissions from the treatment process are estimated to be due to fugitive emissions, while less than 0.001% are due to stationary emissions.

Table 19: Total activity-based emissions from wastewater treatment process (CO_2e, 2012)

Stationary emissions (CH_4)	Process emissions (N_2O)	Fugitive emissions (N_2O)	Total emissions
1	38	741	780

Source: Calculated in this report.

Table 20 summarizes the total activity-based wastewater GHG emissions, including electricity and non-electricity GHG emissions. About three-quarters of total wastewater emissions are from electricity use, with the remainder attributed to the treatment process.

Table 20: Total activity-based wastewater GHG emissions (MT CO_2e, 2012)

Wastewater type	Emissions
Electricity use	2,738
Treatment process	780
Total	**3,517**

Source: Calculated in this report.

Table 21 summarizes the combined activity-based emissions in the drinking water and wastewater treatment sector.

Table 21: Summary of emissions in the drinking water and wastewater treatment sector (MT CO_2e, 2012)

Category	Emissions
Activity-based	
Drinking water	
Treatment	2,802
Distribution	662
Subtotal	**3,464**
Wastewater	
Treatment plant, electricity	2,209
Treatment plant, process	780
Wastewater distribution	529
Subtotal	**3,518**
Total, activity-based	**6,982**

Source: Calculated in this report. Note: Source-based emissions are not calculated for this sector.

4. SOLID WASTE

GHG emissions from solid waste management include those from fuel in equipment used to transport and process the waste and through the decay of biological wastes that have been deposited in the landfill. These emissions include CO_2, CH_4, and N_2O, although the specific proportions depend upon the type of waste management process.

In 1998, the Morgantown landfill—an older unlined landfill located within city limits and adjacent to the municipal airport—was taken out of service and capped (WVDEP, 2014). Decomposing solid waste deposited in the landfill continues to emit GHGs within the city of Morgantown. Unfortunately, a lack of information associated with the configuration and operation of this landfill made it impossible to estimate 2012 emissions from this landfill. If estimated, these would be source-based emissions because they occur within city limits.

Presently, Morgantown's solid waste is managed by Republic Services. Waste is collected from residences, businesses, and industries throughout Morgantown, hauled to a transfer station at the Morgantown Industrial Park, and then loaded and sent to Short Creek Landfill near Wheeling, West Virginia. Short Creek Landfill includes a methane collection system. Based on data provided by Republic Services, 29,175 tons of waste were collected from Morgantown and sent to this landfill in 2012 (Table 22) (Smith, 2014). The data were classified into residential, commercial, and mixed residential and commercial, with the largest amount of waste coming from the commercial sector.

Republic Services also disposed of 3,178 tons of construction and demolition waste (2,938 tons from contracts within the city and 240 tons from WVU). Because there are no methodologies available to calculate GHG emissions from construction and demolition waste, we do not include this waste in our analysis.

Table 22: Solid waste collected from Morgantown and sent to the Short Creek Landfill (short tons, 2012)

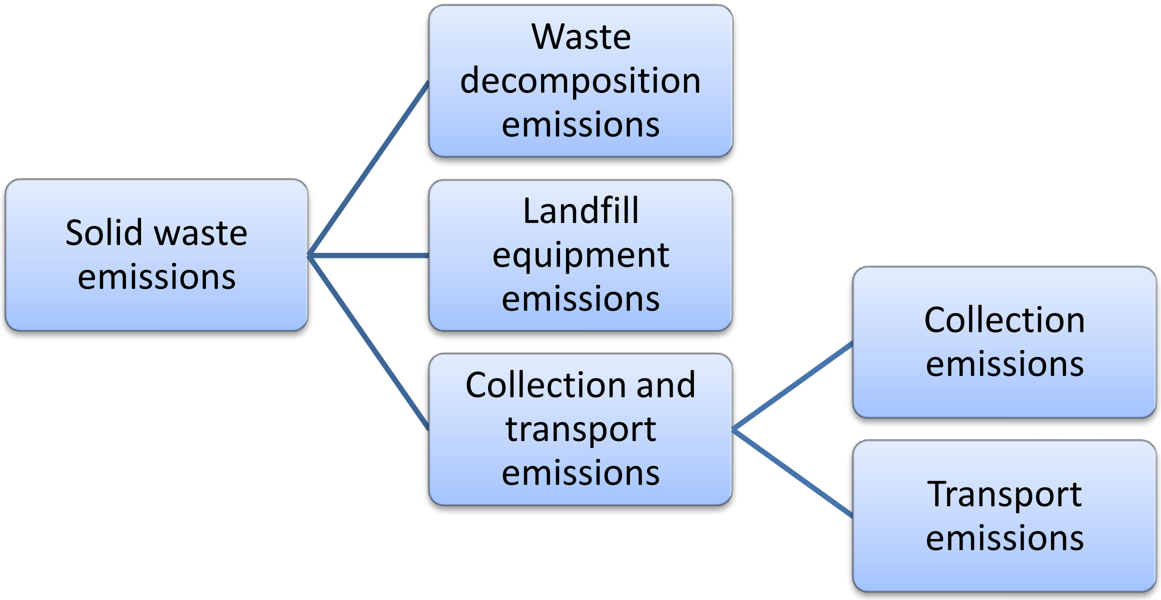
Type	Waste
Residential	9,549
Commercial	13,112
Mixed residential and commercial	6,514
Total	**29,175**

Source: Smith (2014). Note: Mixed residential and commercial waste is associated with rolloff containers, which are typically 30-yard containers used in both commercial and residential applications.

Data that characterize Morgantown's waste stream were not available; therefore, we based our calculations on an average characterization of mixed residential and commercial waste.

GHG emissions from solid waste generated within the city of Morgantown were calculated for three emissions components: 1) collection and transport emissions, 2) landfill equipment emissions, and 3) waste decomposition emissions (Figure 17).

Figure 17: Solid waste management emissions components



As described above, the only source-based solid waste emissions within the city of Morgantown are from the closed Morgantown Landfill; however, we do not estimate these emissions in this report. Instead, we focus on activity-based emissions associated with waste generated by the Morgantown community and transported to the Short Creek Landfill (Table 23).

Table 23: Types of source- and activity-based emissions from the solid waste sector

Source-based emissions	Activity-based emissions
• Emissions from the capped Morgantown Landfill located within the city limits (not calculated due to a lack of data)	• Emissions from community-generated waste deposited and decomposed in landfill • Emissions from the transfer and movement of solid waste at the landfill • Emissions from solid waste collection within Morgantown and transportation to the landfill

Activity-based emissions were calculated because waste is collected and disposed of in a landfill outside of the city limits. Although 2012 data were used in this inventory, the waste disposed during this year will generate emissions over a long period of time. The methods outlined below estimate future emissions resulting from solid waste generated in 2012. Waste decomposition emissions were estimated using Equation 10.

Equation 10: Waste decomposition emissions

$$CH_4\ emissions\ = (1 - CE) \times (1 - OX) \times M\ \times EF \times GWP_{CH4}$$

Source: ICLEI (2012d).

Where:

- CH_4 emissions = Waste decomposition emissions (MT CO_2e/year)
- CE = Default landfill gas collection efficiency (0.75)
- OX = Oxidation rate (0.1)
- M = Total mass of solid waste entering landfill from Table 22 (wet short tons/year)
- EF = Emission factor for mixed residential and commercial waste (0.06 MT CH_4/wet short ton)
- GWP_{CH4} = Global warming potential (21 MT CO_2e/MT CH_4)

Table 24 shows the total waste decomposition emissions by sector. The commercial sector generated 39% of waste decomposition emissions.

Table 24: Waste decomposition emissions (MT CO_2e, 2012)

Sector	Emissions
Residential	2,707
Commercial	3,718
Mixed residential and commercial	1,847
Total	**8,271**

Source: Calculated in this report.

Equipment at the landfill generates CO_2 emissions. Republic Services only uses diesel engines for its operations, as opposed to natural gas or gasoline engines. Equation 11 was used to calculate landfill equipment emissions; results are summarized in Table 25.

Equation 11: Landfill equipment emissions

$$Landfill\ equipment\ emissions = M \times EF$$

Source: ICLEI (2012d).

Where:

- Landfill equipment emissions = Total landfill equipment emissions (MT CO_2e/year)
- M = Total mass of solid waste entering landfill from Table 22 (wet short tons/year)
- EF = Emission factor for landfill equipment emissions (0.0164 MT CO_2e/wet short ton)

Table 25: Landfill equipment emissions (MT CO_2e, 2012)

Sector	Emissions
Residential	157
Commercial	215
Mixed residential and commercial	107
Total	**478**

Source: Calculated in this report.

Collection emissions are predominately CO_2 emissions associated with powering the equipment necessary to collect solid waste from within the community. Transportation emissions cover the transportation of waste from the community to the Short Creek Landfill, which is approximately 79 miles from the city of Morgantown. Equation 12 and Equation 13 were used to calculate collection and transportation emissions associated with solid waste management.

Equation 12: Collection emissions

$$Collection\ emissions = M \times EFC$$

Source: ICLEI (2012d).

Where:

- Collection emissions = Total collection emissions (MT CO_2e/year)
- M = Total mass of solid waste collected and transported and entering landfill (wet short tons/year)
- EFC = Emission factor for collection emissions (0.02 MT CO_2e/wet short ton)

Equation 13: Transportation emissions

$$Transportation\ emissions = M \times Miles\ travelled \times EFT$$

Source: ICLEI (2012d).

Where:

- Transportation emissions = Total transportation emissions (MT CO_2e/year)
- M = Total mass of solid waste collected and transported and entering landfill from Table 22 (wet short tons/year)
- Miles traveled = Distance from Morgantown to the Short Creek Landfill (79 miles)
- EFT = Emission factor for transport emissions (0.00014 MT CO_2e/wet short ton/mile)

As shown in Table 26, collection emissions represent about two-thirds of total collection and transport emissions.

Table 26: Collection and transportation emissions (MT CO_2e, 2012)

Sector	Collection	Transportation	Total
Residential	191	106	**297**
Commercial	262	145	**408**
Mixed residential and commercial	130	72	**202**
Total	**584**	**323**	**906**

Source: Emissions calculated in this report.

Figure 18 illustrates the emissions associated with each component of solid waste management for waste generated in Morgantown, and Figure 19 shows the total emissions per sector.

Figure 18: Emissions from solid waste management (by component, MT CO_2e, 2012)

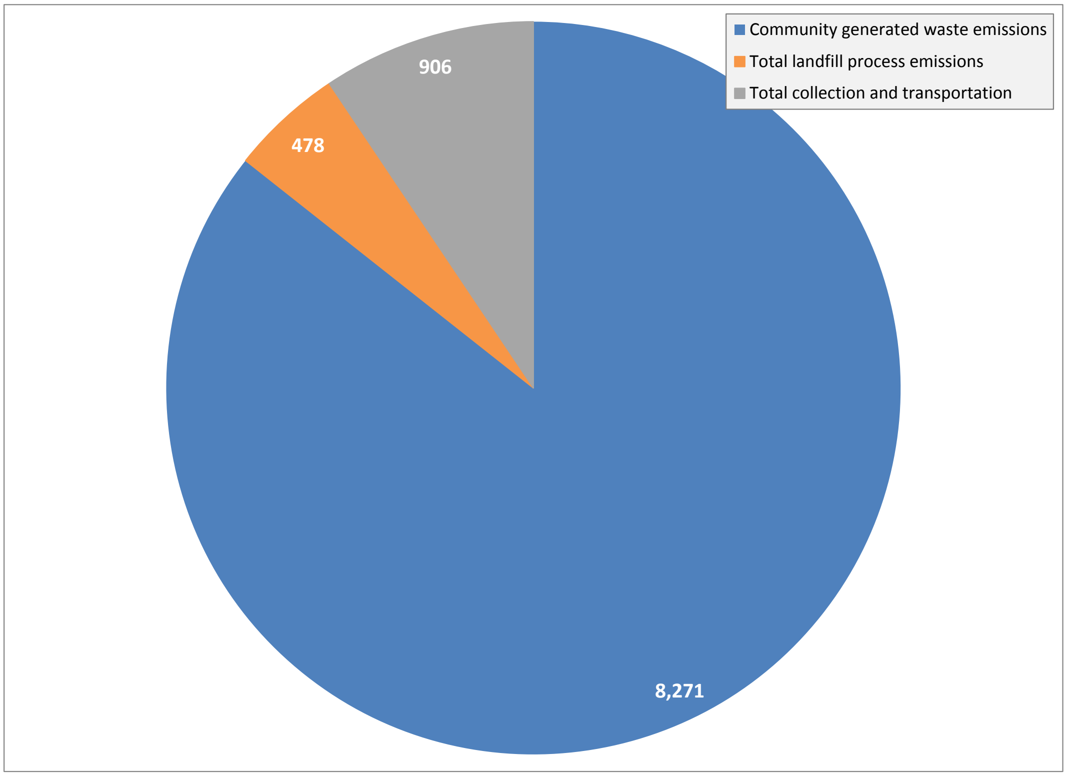


Figure 19: Emissions from solid waste management (by sector, MT CO_2e, 2012)

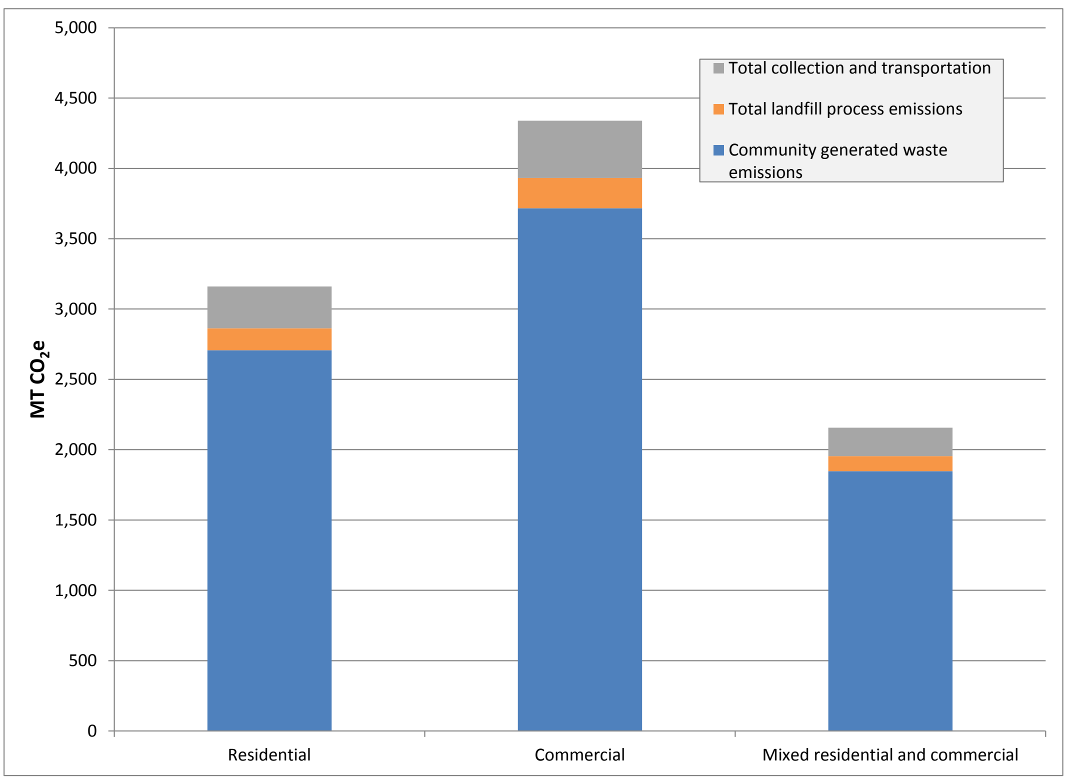


Table 27 summarizes activity-based emissions from solid waste generated within the Morgantown community and disposed of outside of city limits. In 2012, 29,175 short tons of solid waste were sent to the landfill. Including future emissions at the landfill, this waste is responsible for a total of 8,271 MT CO_2e due to decomposition at the landfill. Emissions that take place during the baseline year of 2012, from collection and transportation, add another 1,385 MT CO_2e to the total.

Table 27: Summary of emissions in the solid waste sector (MT CO_2e, 2012)

Category	Emissions
Activity-based	
Decomposition of community-generated waste	8,271
Transfer and movement of solid waste at the landfill	478
Waste collection in Morgantown	584
Transportation of waste to the landfill	323
Total, activity-based	**9,656**

Source: Calculated in this report. Note: Source-based emissions are not calculated for this sector.

5. TRANSPORTATION

This section characterizes emissions associated with transportation fuels used by on-road passenger and freight motor vehicles. Typically there is a lack of precise and accurate data that accounts for travel activity within communities. State, national, and local data collection and mobile emission modeling techniques vary widely. All of these factors played a role in how the transportation emissions were calculated for this report.

We used county-level vehicle miles traveled (VMT) data and county-level Division of Motor Vehicles registration data to estimate activity-based transportation emissions associated with community[6] land uses for the larger Morgantown metropolitan area.

Table 28: Types of source- and activity-based emissions from the transportation sector

Source-based emissions	Activity-based emissions
• Not calculated due to lack of appropriate data	• Direct emissions from on-road passenger vehicle travel associated with community land uses • Direct emissions from on-road freight and service truck travel associated with community land uses • Emissions from lifecycle of transportation fuels

In the US, transportation activities contribute emissions that are associated with the movement of people and goods. The transportation sector represents one of the largest sources of GHG emissions in most communities (ICLEI, 2012e). The majority of GHG emissions from transportation are CO_2 emissions resulting from the combustion of petroleum-based products, like gasoline or diesel fuel, in internal combustion engines. The largest sources of transportation-related GHG emissions include passenger cars and light duty trucks, including sport utility vehicles, pickup trucks, and minivans. These sources account for over half of the emissions from the sector (ICLEI, 2012e). The remainder of GHG emissions comes from other modes of transportation, including freight trucks, commercial aircraft, ships, boats, and trains (USEPA, 2014f).

The Morgantown Monongalia Metropolitan Planning Organization (MMMPO) is the federally-designated transportation planning agency for Morgantown and Monongalia County, serving as a regional partnership among the West Virginia Department of Transportation, local transit agency, local elected leadership, local planning and public works directors, business community, and citizens. The MMMPO has the authority to plan, prioritize, and recommend transportation projects for federal and state funding. It is also responsible for ensuring the region is in compliance with federal and state multi-modal transportation planning requirements (City of Morgantown, 2013c).

In late 2011 and early 2012, MMMPO started the process of updating its regional Long Range Transportation Plan (LRTP). This effort coincided with the development of comprehensive plans for the City of Morgantown and Star City. The LRTP established goals and objectives for the 2013-2040 planning period. It incorporated the regional vision and federally mandated Metropolitan Planning Factors and was refined further by the Transportation Advisory Group (MMMPO, 2012a).

[6] "Community" refers to residents, businesses, industries, and government co-located within a defined jurisdiction. Across each mode, travel by members of the community often involves crossing the community boundary with a portion of travel occurring outside the community (ICLEI, 2012a).

Eight goals were established through this process, with several objectives associated with each goal that, if implemented, would help reduce GHG emissions in the Morgantown area. Examples of these objectives include:

- eliminating and/or reducing current congestion and multimodal traffic flow restrictions on arterial and collector roadways;
- allowing for convenient transfer from one mode to another in the region (i.e., biking to bus, vanpooling to bus, etc.) to maximize travel efficiency;
- increasing the geographic area in which people have convenient access to non-automobile modes of transportation;
- reducing automobile emissions and improving air quality;
- increasing trips made by walking and by bicycle,
- increasing the number of trips made by public transit by 200%;
- increasing telecommuting and virtual lectures at WVU; and
- increasing average vehicle occupancy by 50%. (MMMPO, 2012a)

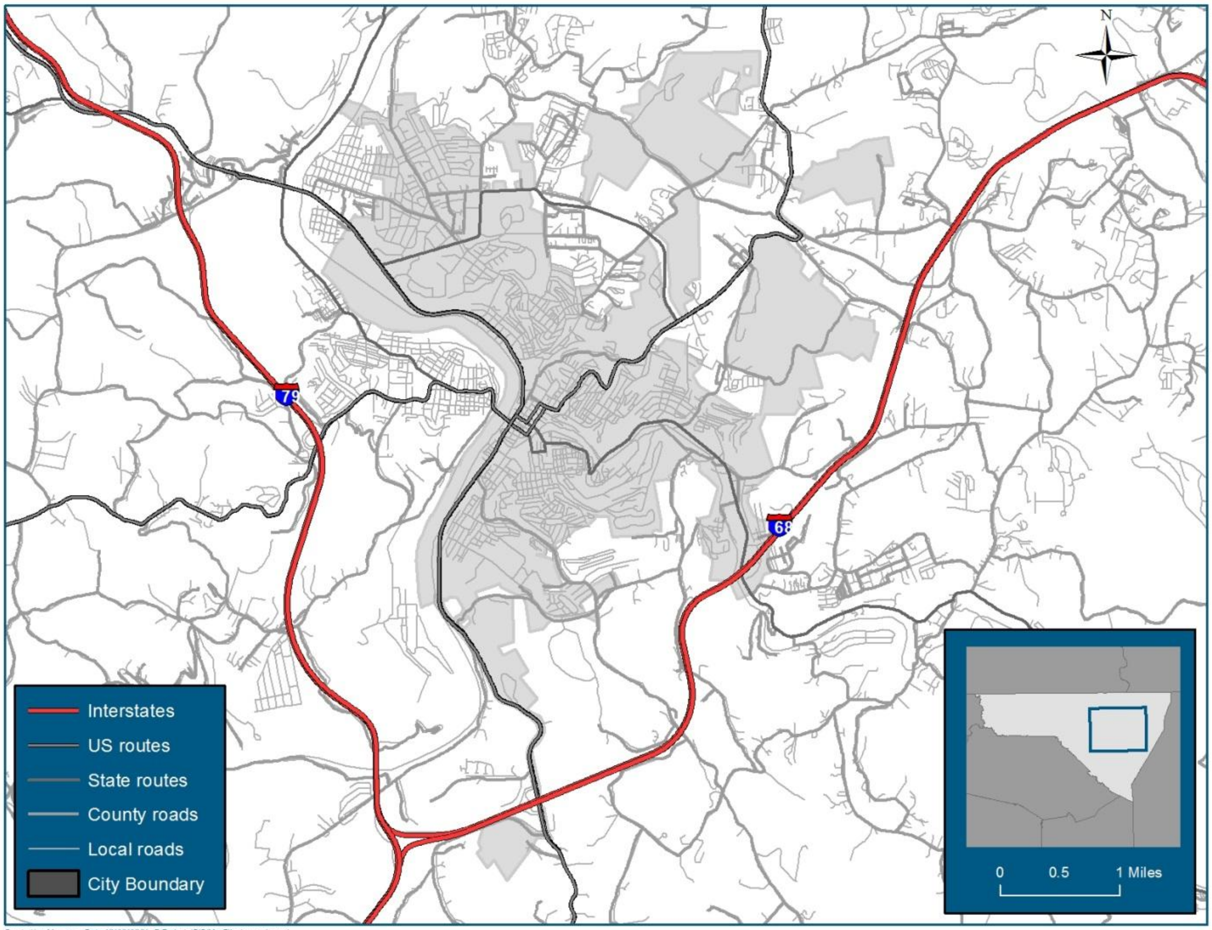
Figure 20 shows the transportation network within and outside of Morgantown. Morgantown-area traffic volumes and operating conditions are influenced heavily by the activities at WVU. These factors have been incorporated into the LRTP to better reflect traffic volumes when WVU is in session. The level of service measured in Morgantown—which is an often-used measure of the acceptability of roadway delay to the traveler—shows that there are several road segments rated at maximum capacity or forced flow. Extended and excessive delays result from these conditions (MMMPO, 2012b).

As part of the LRTP update process, MMMPO updated its transportation demand model, which can determine how much demand for transportation services the region should expect in the future, based on changing conditions (MMMPO, 2012c). This modeling effort produced VMT data for MMMPO's management area and was an important input into the mobile source GHG emissions calculated in this chapter. VMT is a measure of the level of travel within an area and is calculated by multiplying the length of a link by the number of cars travelling on that link (MMMPO, 2012c). MMMPO estimates that the average daily VMT for Monongalia County was 2.51 million in 2010, the most recent year for which data are available (MMMPO, 2012c). This corresponds to 916 million VMT per year.

There are five steps that represent the full fuel cycle for emissions associated with transportation fuels:

1. feedstock recovery,
2. feedstock transportation,
3. fuel production,
4. fuel transportation, and
5. in-vehicle combustion. (ICLEI, 2012e)

Figure 20: Morgantown transportation network



We begin by calculating direct emissions from passenger, freight, and service vehicles (Step 5). We then apply emission factors to the results for direct emissions to calculate upstream emissions (Steps 1-4).

Mobile GHG emissions associated with transit vehicle emissions are not calculated in this report due to a lack of data and because GHG emissions associated with transit activity represent a very small portion[7] of transportation-related emissions.

MMMPO is not required to model mobile air emissions for the Morgantown area because it is considered to be in attainment with National Ambient Air Quality Standards. If this were not the case, mobile emissions data at the county level would be available to use in the transportation emissions calculations that are described below. Without the benefit of prior modeling efforts for the larger Morgantown metropolitan area, it is difficult to calculate transportation emissions associated with the defined study area. Instead, datasets available at the county level are used to estimate county-wide transportation emissions using VMT and local vehicle mix data. These county-wide emissions estimates are then scaled down in an effort to remove emissions associated with interstate pass-through traffic and emissions associated with Monongalia County residents outside of the Morgantown community. Scaling down the county results improves the mobile emission estimates associated with the city of Morgantown.

[7] All bus- and rail-related emissions (some of which are not transit-based) totaled less than 4% of US transportation emissions in 2010 (ICLEI, 2012e).

Travel activity and emissions per mile traveled are the two primary inputs typically used to model transportation emissions. If available, data characterizing local vehicle efficiency and fuel type are incorporated into the model so that the model better represents local trends.

For travel activity data, an estimate of VMT was used that incorporates all roads within the county and that is based on the LRTP travel demand model that was calibrated to observed traffic counts (MMMPO, 2012d).

For emission factors, we use data presented by ICLEI as well as data published by the Bureau of Transportation Statistics. This includes data on GHG emission rates per mile traveled or per unit of fuel consumed and average miles per gallon for the different vehicle source type categories.

Lastly, county-level vehicle registration information was obtained to identify the local vehicle mix. These data are used to allocate the VMT proportionately to those vehicle categories. Table 29 presents counts of passenger and freight vehicles registered in Monongalia County.

Table 29: Passenger and freight vehicles registered in Monongalia County (2010)

Vehicle type	Count
Passenger vehicles	
Motorcycle	2031
Passenger car	25,921
Passenger truck	24,948
Total, passenger vehicles	**52,900**
Freight vehicles	
Light commercial truck	4,637
Single unit short-haul truck	1,579
Single unit long-haul truck	180
Combination short-haul truck	611
Combination long-haul truck	678
Total, freight vehicles	**7,685**

Source: WVDEP DAQ (2014).

5.1 Passenger vehicles

Equation 14 was used to calculate direct CO_2 emissions from passenger vehicles. This equation was applied separately for each type of passenger vehicle: motorcycles, passenger cars, and passenger trucks.

Equation 14: Direct passenger vehicle CO_2 emissions

$$Passenger\ vehicle\ CO_2 emissions = VMT \times \%\ passenger\ vehicle\ type \div Average\ MPG \times EF \times 0.001$$

Source: ICLEI (2012e).

Where:

- Passenger vehicle CO_2 emissions = Total emissions of CO_2 (MT CO_2e/year)
- VMT = Vehicle miles traveled (916 million miles/year)
- % passenger vehicle type = Percent of VMT associated with each type of passenger vehicles from Table 30
- Average MPG = Average miles per gallon for passenger vehicles from Table 30 (miles/gallon)
- EF = Emission factor (8.78 kg CO_2/gallon)
- 0.001 = Conversion factor (MT/kg)

Equation 15 was used to calculate CH_4 and N_2O emissions from passenger vehicles. The equation was solved first for CH_4 using the emission factor and global warming potential for CH_4 and was solved a second time using the emission factor and global warming potential for N_2O. This equation was also applied separately for each of the three types of passenger vehicles.

Equation 15: Direct passenger vehicle CH_4 and N_2O emissions

$$Passenger\ vehicle\ emissions = VMT \times \%\ passenger\ vehicle\ type \times EF \times 0.000001 \times GWP$$

Source: ICLEI (2012e).

Where:

- Passenger vehicle emissions = Total emissions from passenger vehicles (MT CO_2e/year)
- VMT = Vehicle miles traveled (916 million miles/year)
- % passenger vehicle type = Percent of VMT associated with each type of passenger vehicle from Table 30
- EF = Emission factor (motorcycle 0.001344 grams CH_4/mile, passenger car 0.0107 grams CH_4/mile, passenger truck 0.0178 grams CH_4/mile, motorcycle 0.000138 grams N_2O/mile, passenger car 0.0153 grams N_2O/mile, passenger truck 0.0228 grams N_2O/mile)
- 0.000001 = Conversion factor (MT/gram)
- GWP = Global warming potential (21 MT CO_2e/MT CH_4 , 310 MT CO_2e/MT N_2O)

The results from these three separate calculations (CO_2, CH_4, and N_2O) were summed to generate total CO_2e direct passenger vehicle emissions at the county level.

5.2 Freight and service trucks

The method used to estimate CO_2 emissions from freight and service trucks is similar to the method used for passenger vehicles. For freight and service trucks, Equation 16 was applied separately for each type of truck: light commercial (gas), single unit short-haul (gas and diesel), single unit long-haul (gas and diesel), combination short-haul (gas and diesel), and combination long-haul (gas and diesel).

Equation 16: Freight and service truck CO_2 emissions

$$Freight\ and\ service\ truck\ CO_2 emissions = VMT \times \%\ freight\ and\ service\ truck\ type\ \div Average\ MPG \times EF \times 0.001$$

Source: ICLEI (2012e).

Where:

- Freight and service truck CO_2 emissions = Total emissions of CO_2 (MT CO_2e/year)
- VMT = Vehicle miles traveled (916 million miles/year)
- % freight and service truck type = Percent of VMT associated with each type of freight and service truck from Table 31
- Average MPG = Average miles per gallon for freight and service trucks from Table 31 (miles/gallon)
- EF = Emission factor (gasoline 8.28 kg CO_2/gallon, diesel 10.21 kg CO_2/gallon)
- 0.001 = Conversion factor (MT/kg)

The method used to estimate CH_4 and N_2O emissions from freight and service trucks is similar to the method used for passenger vehicles. For freight and service trucks, Equation 17 was applied twice—once for CH_4 using the emission factor and global warming potential for CH_4, and a second time for N_2O, using the emission factor and global warming potential for N_2O. This equation was also applied separately for each of the nine types of freight and service trucks.

Equation 17: Freight and service truck CH_4 and N_2O emissions

$$Freight\ and\ service\ truck\ emissions = VMT \times \%\ freight\ and\ service\ truck\ type \times EF \times 0.000001 \times GWP$$

Source: ICLEI (2012e).

Where:

- Freight and service truck emissions = Total emissions from freight and service trucks (MT CO_2e/year)
- VMT = Vehicle miles traveled (916 million miles/year)
- % freight and service truck type = Percent of VMT associated with each type of freight and service truck from Table 31
- EF = Emission factor (light commercial 0.0178 grams CH_4/mile, short and long haul gasoline 0.0333 grams CH_4/mile, short and long haul diesel 0.0051 grams CH_4/mile, light commercial truck 0.0228 grams N_2O/mile, short and long haul gasoline 0.0134 grams N_2O/mile, short and long haul diesel 0.0048 grams N_2O/mile)
- 0.000001 = Conversion factor (MT/gram)
- GWP = Global warming potential (21 MT CO_2e/MT CH_4 , 310 MT CO_2e/MT N_2O)

The results from these three separate calculations (CO_2, CH_4, and N_2O) were summed to generate total CO_2e direct freight and service truck emissions at the county level.

5.3 Upstream emissions

We calculate upstream emissions—which include feedstock recovery, feedstock transportation, fuel production, and fuel transportation (Steps 1-4 described above)—by applying a scaling factor to the direct emissions calculated above. Equation 18 was used to calculate these upstream emissions. This equation was applied separately for CO_2, CH_4, and N_2O.

Equation 18: Upstream transportation emissions

$$Upstream\ emissions = Direct\ emissions \times Scaling\ factor$$

Source: ICLEI (2012e).

Where:

- Upstream emissions = Upstream emissions from all transportation fuels, including feedstock recovery, feedstock transportation, fuel production, and fuel transportation (MT CO_2e/year)
- Direct emissions = Direct CO_2, CH_4, and N_2O emissions for all passenger vehicles and freight and service trucks calculated above (MT CO_2e/year)
- Scaling factor = Fuel-specific scaling factor of life-cycle emissions to direct emissions (0.25 for "Gasoline – low-level (~10%) corn ethanol blend" and for "Diesel – conventional and low-sulfur," the two fuel types used in this analysis.)

Table 30 and Figure 21 show the breakdown of Monongalia County registered vehicles, for 2010, across each class and detail the calculated GHG emissions. Passenger trucks, representing 41% of registered passenger vehicles, contribute more GHG emissions than motorcycles or passenger cars. GHG emissions across all passenger vehicle classes produced 442,900 MT CO_2e. Upstream emissions make up 20% of total emissions for passenger vehicles that use gasoline for fuel.

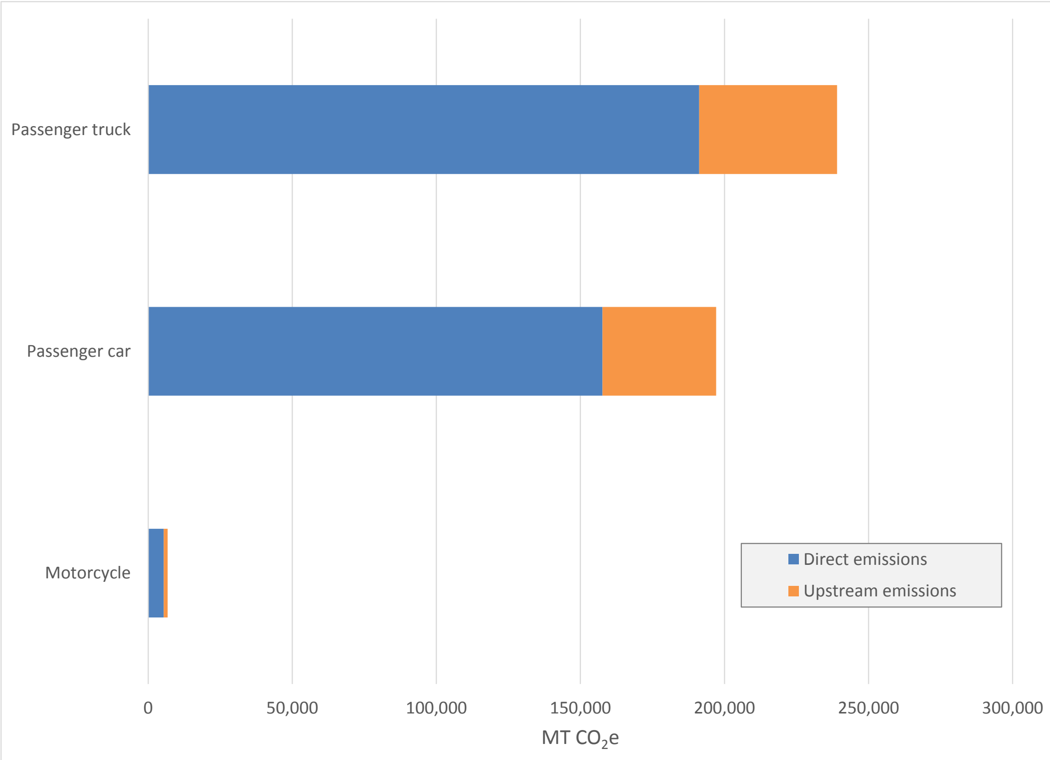
Table 31 and Figure 22 display the county-level GHG emissions associated with freight and service trucks. Light commercial trucks, using gasoline as fuel, contributed the largest amount of GHG emissions from freight and service trucks in 2010, with 41,941 MT CO_2e produced, which represents 32% of the total. Single-unit short-haul trucks, using diesel as fuel, were the second-largest contributor of GHG emissions among freight and service trucks, producing 29,059 MT CO_2e. Across all nine classes, freight and service trucks emitted a total of 132,613 MT CO_2e across Monongalia County in 2010.

Table 30: Emissions from passenger vehicles (Monongalia County, 2010)

Vehicle type	Percent of vehicles	Average miles per gallon (2002)	Emissions (MT CO_2e)		
			Direct	Upstream	Total
Passenger truck	41%	17.5	191,253	47,813	239,066
Passenger car	43%	22	157,695	39,424	197,119
Motorcycle	3%	50	5,372	1,343	6,715
Total	**NA**	**NA**	**354,320**	**88,580**	**442,900**

Sources: Percent of vehicles from WVDEP DEQ (2014). Average miles per gallon from Bureau of Transportation Statistics (2013) and ICLEI (2012e). Emissions calculated in this report.

Figure 21: Emissions from passenger vehicles (Monongalia County, 2010)



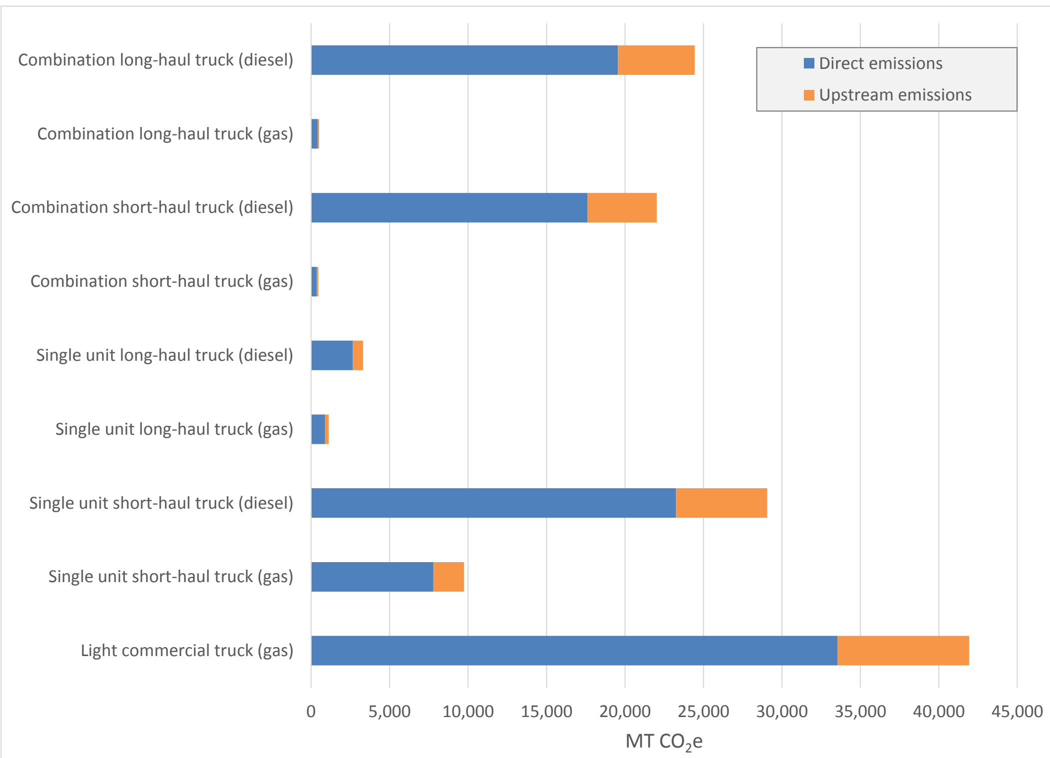
Source: Calculated in this report.

Table 31: Emissions from freight and service trucks (Monongalia County, 2010)

Vehicle type	Percent of vehicles	Average miles per gallon (2002)	Emissions (MT CO_2e) Direct	Upstream	Total
Light commercial truck (gas)	8%	17.5	33,553	8,388	41,941
Single-unit short-haul truck (gas)	1%	7.4	7,800	1,950	9,750
Single-unit short-haul truck (diesel)	2%	7.4	23,247	5,812	29,059
Single-unit long-haul truck (gas)	<1%	7.4	890	222	1,112
Single-unit long-haul truck (diesel)	<1%	7.4	2,652	663	3,315
Combination short-haul truck (gas)	<1%	5.2	367	92	459
Combination short-haul truck (diesel)	1%	5.2	17,619	4,405	22,024
Combination long-haul truck (gas)	<1%	5.2	408	102	509
Combination long-haul truck (diesel)	1%	5.2	19,555	4,889	24,444
Total	**13%**	**NA**	**106,091**	**26,523**	**132,613**

Sources: Percent of vehicles from WVDEP DAQ (2014). Average miles per gallon from Bureau of Transportation Statistics (2014a, b, and c). Emissions calculated in this report.

Figure 22: Emissions from freight and service trucks (Monongalia County, 2010)



Source: Calculated in this report.

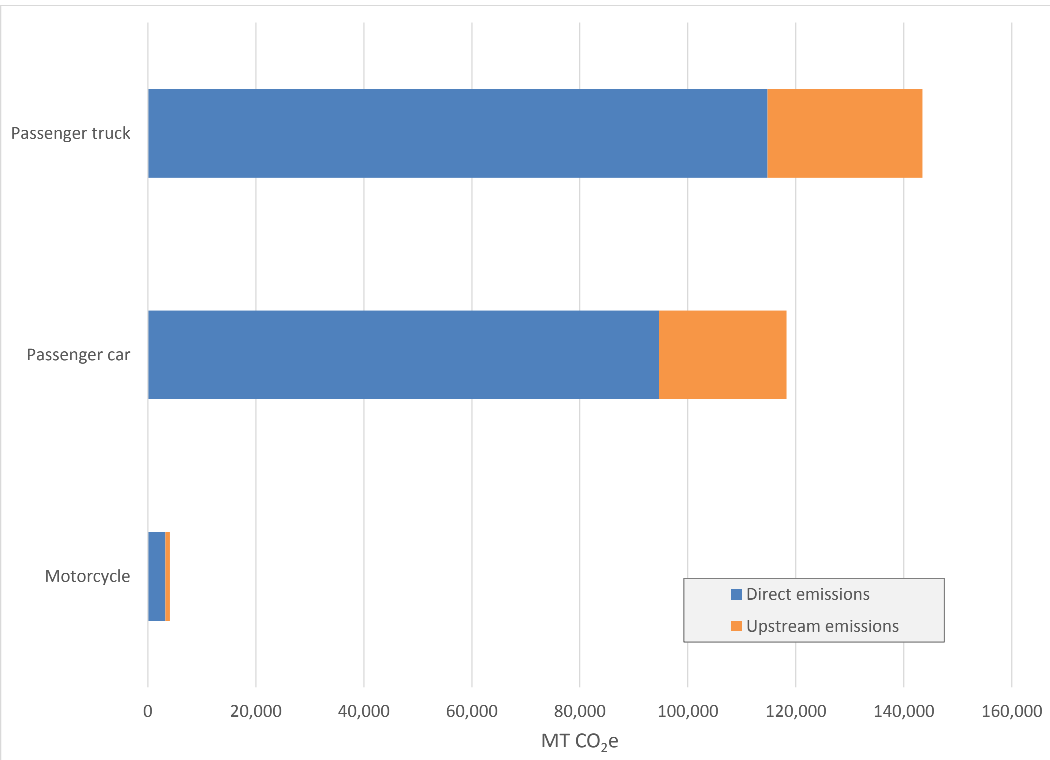
As noted above, the estimates calculated above represent county-level transportation emissions as best calculated using available data. In an effort to better represent activity-based transportation emissions associated with the Morgantown community, the county-level emission estimates are reduced. There is no precise method available to account for the resident city population, the population of the county, and the daytime city population increases due to Morgantown being the primary attraction for employment and services within the region. There is also no precise method available that takes into account which VMT are driven by city residents, those that live elsewhere in Monongalia County, and those that live outside of the county. Still, even though a precise method is not available, there is no doubt that the actual activity-based emissions from the transportation must be less than that calculated for the county as a whole. We choose to reduce the county-level emissions estimates by 40% as a first-cut approximation that accounts for this range of hard-to-quantify factors. Table 32, Table 33, Figure 23, and Figure 24 summarize our calculations for the Morgantown community, after reducing the county-level emissions by 40%.

Table 32: Emissions from passenger vehicles (Morgantown community, MT CO_2e, 2010)

Vehicle type	Direct	Upstream	Total
Passenger truck	114,752	28,688	**143,440**
Passenger car	94,617	23,654	**118,271**
Motorcycle	3,223	806	**4,029**
Total	**212,592**	**53,148**	**265,740**

Source: Calculated in this report.

Figure 23: Emissions from passenger vehicles (Morgantown community, MT CO_2e, 2010)



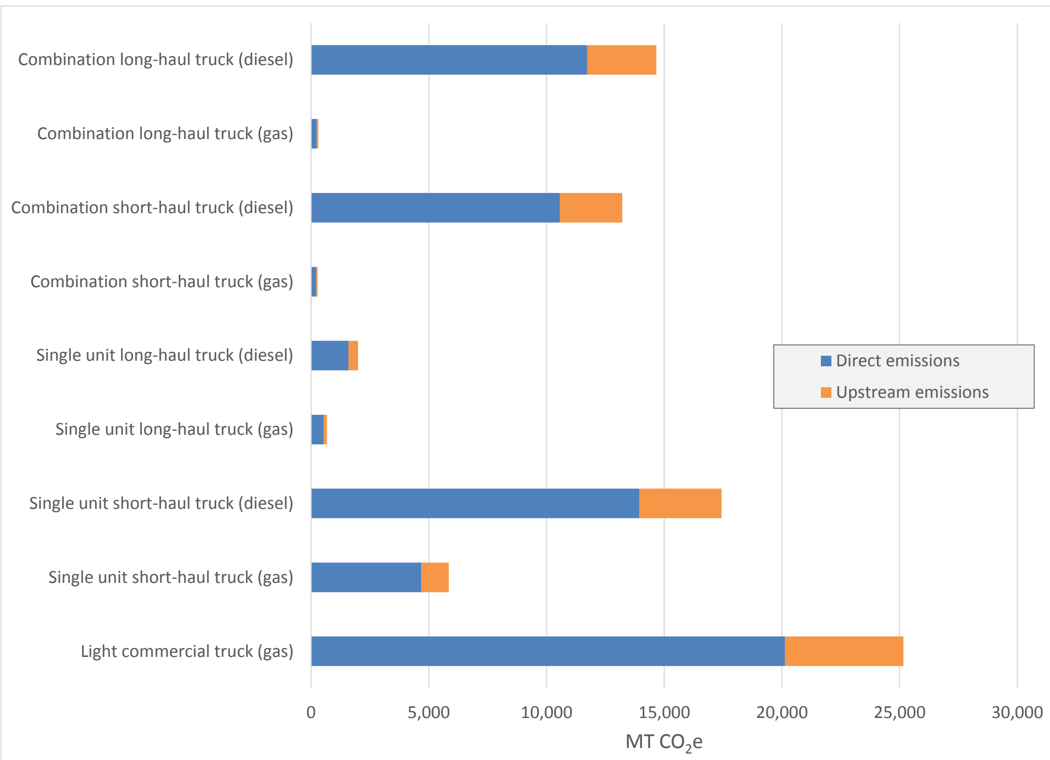
Source: Calculated in this report.

Table 33: Emissions from freight and service trucks (Morgantown community, MT CO_2e, 2010)

Vehicle type	Direct	Upstream	Total
Light commercial truck (gas)	20,132	5,033	**25,165**
Single unit short-haul truck (gas)	4,680	1,170	**5,850**
Single unit short-haul truck (diesel)	13,948	3,487	**17,435**
Single unit long-haul truck (gas)	534	133	**667**
Single unit long-haul truck (diesel)	1,591	398	**1,989**
Combination short-haul truck (gas)	220	55	**275**
Combination short-haul truck (diesel)	10,571	2,643	**13,214**
Combination long-haul truck (gas)	245	61	**306**
Combination long-haul truck (diesel)	11,733	2,933	**14,666**
Total	**63,654**	**15,914**	**79,568**

Source: Calculated in this report.

Figure 24: Emissions from freight and service trucks (Morgantown community, MT CO_2e, 2010)



Source: Calculated in this report.

Table 34 summarizes the activity-based community-generated GHG emissions associated with the transportation sector. Transportation emissions total 345,508 MT CO_2e, with GHG emissions from the passenger vehicle category contributing 77% of the transportation-related mobile emissions.

Table 34: Summary of emissions in the transportation sector (Morgantown community, MT CO_2e, 2012)

Category	Emissions
Activity-based	
Passenger vehicles	
Direct emissions	212,592
Upstream emissions	53,148
Subtotal	**265,740**
Freight and service trucks	
Direct emissions	63,654
Upstream emissions	15,914
Subtotal	**79,568**
Total, activity-based	**345,308**

Source: Calculated in this report. Note: Source-based emissions are not calculated for this sector.

6. MUNICIPAL EMISSIONS AND SUSTAINABILITY EFFORTS

The City of Morgantown has implemented a host of sustainability programs over time in an effort to decrease resource use and improve the livability of Morgantown; several of these efforts have also reduced GHG emissions. In 2007, Morgantown was one of four West Virginia cities to sign on to the US Mayors Climate Protection Agreement (US Conference of Mayors, 2007). By signing this agreement, the City agreed to initiate efforts that would help reduce GHG emissions.

One of the first actions taken by the City involved the formation of the Morgantown Municipal Green Team. The Green Team was established by the City Manager to serve as an advisory body to the City Manager and City Council in helping to guide public policy, planning, education, departmental management, new development, and evaluation of environmental and energy-related matters (City of Morgantown, 2014b).

This section highlights emissions associated with City operations that could be extracted using data and results from the Morgantown community inventory. It then highlights programs that have been implemented that have helped and can help in the future to reduce GHG emissions associated with these activities.

6.1 Emissions

Billed electricity end-use data, for buildings where data were available, were provided by City engineering staff for 2012. In total, this subset of City buildings consumed 2,287 MWh, with associated 2012 direct emissions of 1,568 MT CO_2e.[8]

A monthly breakdown of electricity consumption for each building can be found in Figure 25, with associated emissions detailed in Figure 26. The Public Safety Building, which houses police and fire personnel as well as the Municipal Court and Parking Authority, is the largest user of electricity of any single City building, according to the data that were provided. The building is large, a multi-story parking garage is attached, and it is occupied 24 hours a day.

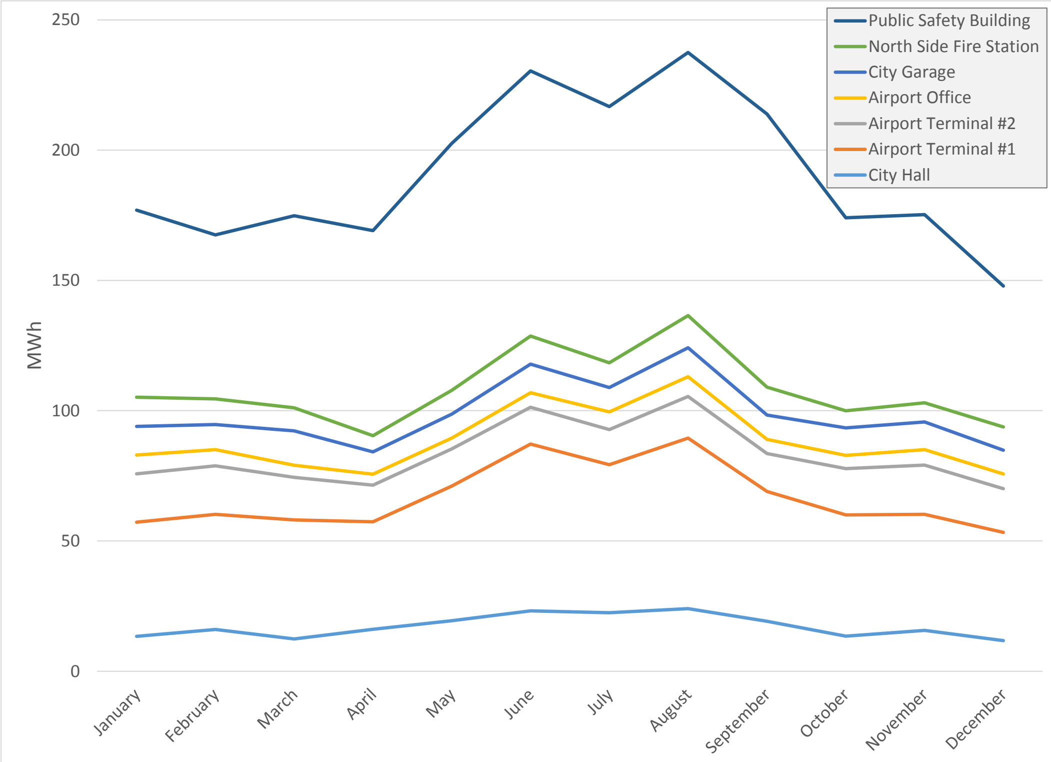
Street lights also consume a large amount of electricity and therefore emit a large amount of GHG emissions. Data on utility-owned street lights were not available because they are not metered. Instead, the City pays a flat rate per street light under a tariff-based billing arrangement between the City and Mon Power (Lloyd, 2014a).

These City buildings account for less than 1% of the overall total electricity use within the city of Morgantown in 2012 (See the activity-based total emissions from the electricity sector of 347,434 MT CO_2e in Table 3).

Other City buildings and infrastructure that potentially consume large amounts of electricity, but for which data were not provided, include the city ice rink, traffic signals, Southside and Norwood fire stations, public library, and Metropolitan Theatre (Lloyd, 2014a). Although this report does not calculate GHG emissions associated with these buildings, the City is addressing energy consumption through the Guaranteed Energy Services Agreement discussed in Section 6.2.

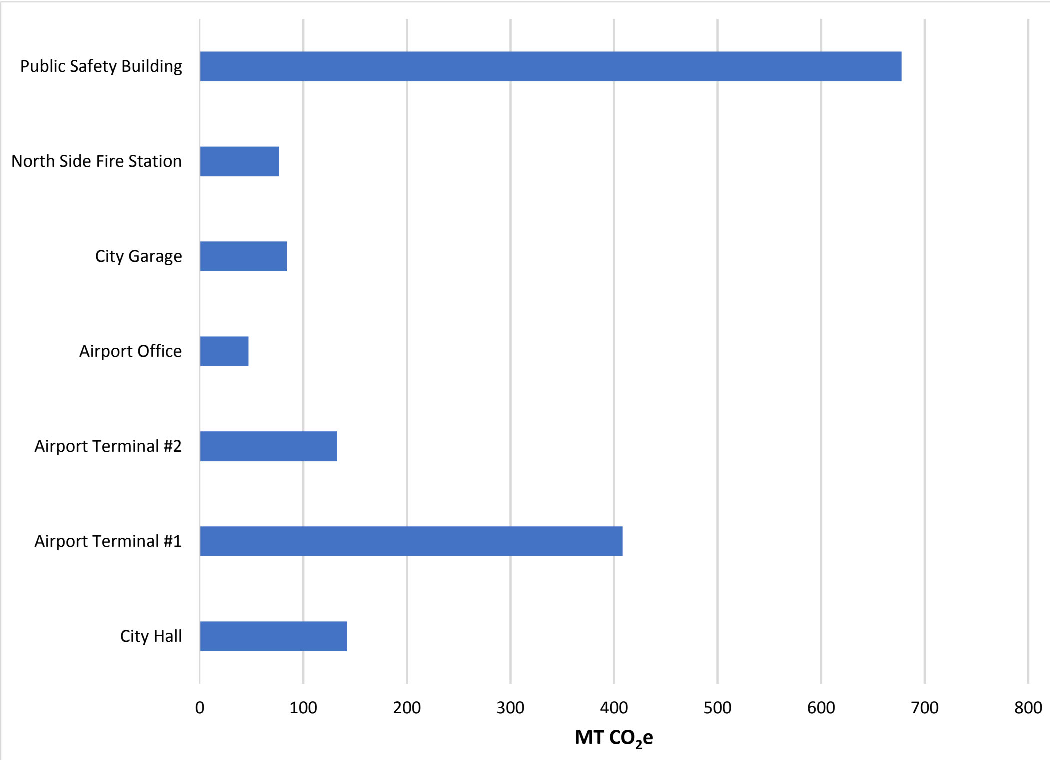
[8] Emissions are calculated using Equation 1.

Figure 25: Monthly billed electricity use for City buildings (MWh, 2012)



Source: Lloyd (2013a).

Figure 26: Total end-use emissions for City buildings (MT CO_2e, 2012)



Source: Calculated in this report.

City-billed natural gas data over its 19 natural gas accounts for 2012 were provided by Dominion Hope. The City consumed 70,644 Mcf in 2012 (Morris, 2014b), which is almost 5% of total amount of natural gas consumed within Morgantown (See Table 5). The emissions associated with the City's natural gas consumption released 3,860 MT CO_2e in source-based emissions and 4,750 MT CO_2e in activity-based emissions.[9] Data that correspond with each account were not available for analysis.

As described in Chapter 3, MUB is the municipally owned drinking water and wastewater utility that provides service to most of the residents that live in and around Morgantown, including City buildings within Morgantown. A portion of emissions, detailed in Table 21, are associated with the treatment and distribution of both water and wastewater associated with City operations; however, data to support calculations that would identify the City's contribution to total emissions were not available.

Waste generated within City buildings is picked up by Republic Services, delivered to the transfer station, and transported to the Short Creek Landfill in Wheeling. A portion of the emissions detailed in Table 27 is associated with City waste; however, data were not available to calculate waste volume and associated emissions from City-generated solid waste.

The City owns and operates a large fleet of vehicles and equipment across multiple departments. Table 35 details the number of vehicles and the model year range by department for the City vehicle fleet in 2012.

[9] These emissions are based on calculations that apply Equation 4 and Equation 6.

Table 35: Number of vehicles and model year range of the City vehicle fleet (2012)

Department	No. of vehicles	Model year range
Airport	7	1981 - 2005
Beautification Commission	1	2001
Code Enforcement	12	1997 - 2011
Engineering	6	1999 - 2006
Fire	20	1978 - 2009
Parking Authority	4	2002 - 2010
Police	54	2002 - 2011
Signs	4	1996 - 2005
Street Department	34	1977 - 2011
Total	**142**	**N/A**

Source: Lloyd (2013b).

The Police and Street Department together own over 50% of the total City vehicle fleet. Data on fuel consumption per vehicle and vehicle miles driven were not available for analysis. A portion of the emissions detailed in Table 34 is associated with the fleet of City vehicles listed in Table 35.

6.2 Sustainability efforts

In 2009, the City entered into a Guaranteed Energy Service Agreement with Constellation, an Exelon company (Constellation, 2013). This agreement is considered an energy-savings performance contract (ESPC). An ESPC constitutes a partnership between a facility owner and an energy service company and is considered a time- and cost-effective method for completing comprehensive energy upgrades (USDOE, undated(a)). In other words, an ESPC is a financial mechanism used to pay for today's facility upgrades with tomorrow's energy savings (USDOE, undated(a)). The agreement between the City and Constellation included a total of 10 energy conservation measures, which affect 16 facilities/areas within Morgantown. Measures include:

- interior lighting upgrades;
- traffic signal upgrades;
- pipe insulation;
- variable frequency drive air handling;
- boiler upgrades;
- a new metal roof;
- new garage door panels;
- city ice rink chiller replacement;
- heated hot water boiler installation;
- installations of two tank-less hot water heaters; and
- heating, ventilation, and air conditioning upgrades. (Constellation, 2013)

As part of the ESPC, Constellation is required to calculate utility cost savings each year. According to Constellation's estimates, this contract saved $231,684 in 2012 (Constellation, 2013). This includes a reduction in natural gas consumption of 5,176 Mcf and a reduction of 1,738 MWh of electricity use, which corresponds with a reduction of end-use GHG emissions of 283 MT CO_2e and 1,192 MT CO_2e, respectively.

The installation of solar panels on the Morgantown Farmers Market Pavilion is another effort that the City has supported that directly offsets GHG emissions associated with electricity generation. In 2013, twelve solar panels were installed on the roof of the pavilion; these solar panels produce electricity that directly offset City electricity expenses through a net metering arrangement with Mon Power. An electric vehicle charging station allows users of the lot to charge their vehicles.

As of May 20, 2014, the solar panels had produced 4.26 MWh of electricity and had offset 3.4 MT CO_2e in total GHG emissions, which includes emissions associated with end-use, transmission and distribution losses, and upstream emissions (City of Morgantown, 2014c and data calculated in this report).[10]

Figure 27: Solar panels installed on the Morgantown Farmers Market Pavilion

Photo credit: Evan Hansen.

In an effort to reduce the volume of solid waste that enters the landfill, the City has set a goal to reverse the 80%:20% trash-to-recycling-ratio to 80% recycling and 20% trash. An important initiative that supports this goal is the single-stream recycling program that started in October 2012. Other communities that have implemented similar programs have seen recycling participation increase by more than 25% and the actual materials recovered for reuse increase by more than 85% (City of Morgantown, 2014d).

Based on the calculations contained within Section 4 of this report, using the total emissions summary results contained in Table 27 and using the total volume of waste collected from Table 22, we determined that each ton of waste produces approximately 0.33 MT CO_2e, including emissions during collection, transportation, and at the landfill. Reducing overall waste generation and diverting waste from the landfill through recycling efforts can have a major impact on the reduction of GHG emissions associated with community solid waste handling and disposal, which the identified City goal supports.

[10] These emission reductions are calculated in this report using Equation 1, Equation 2, and Equation 3.

As discussed in Section 5, GHG emissions from mobile sources in and around the city are significant. Encouraging alternative modes of transportation such as public transit, vanpools, or human-powered modes of transportation will only help decrease traffic congestion and reduce GHG emissions. The City, in partnership with the MMMPO, has initiated such programs within Morgantown and the surrounding area that will help reduce traffic and emissions from mobile sources. Examples include:

- walkability goals established with the 2013 Comprehensive Plan,
- the MMMPO vanpool program, and
- the adoption of the Morgantown Bicycle Plan.

7. WEST VIRGINIA UNIVERSITY EMISSIONS AND SUSTAINABILITY EFFORTS

Through the Office of Sustainability, WVU has made a commitment to implement sustainability efforts that will benefit its students, faculty, staff, and the citizens of West Virginia (West Virginia University, 2014b). This WVU commitment includes the following components:

- Members of the WVU community (faculty, students, and staff) will have a basic understanding of sustainable practices, communicated through informal learning sessions and the incorporation of sustainability issues into the university curricula.
- WVU will encourage and support sustainability scholarship and research.
- WVU will strive to incorporate sustainable practices into its operations and business processes, which includes purchasing green, incorporating green concepts into building design and maintenance, promoting recycling, and encouraging energy and water conservation in all campus buildings. (West Virginia University, 2014b)

This section highlights emissions associated with WVU operations that could be extracted using data and results from the Morgantown community inventory. It then highlights programs that have been implemented that have reduced and can continue to reduce GHG emissions associated with these activities.

7.1 Emissions

Billed end-use electricity data were provided by the WVU Office of Sustainability, by month, for 2012. In total, WVU consumed 127,183 MWh of electricity, with associated direct emissions totaling 87,200 MT CO_2e.[11] Figure 28 details monthly billed electricity end-use and associated emissions for WVU.

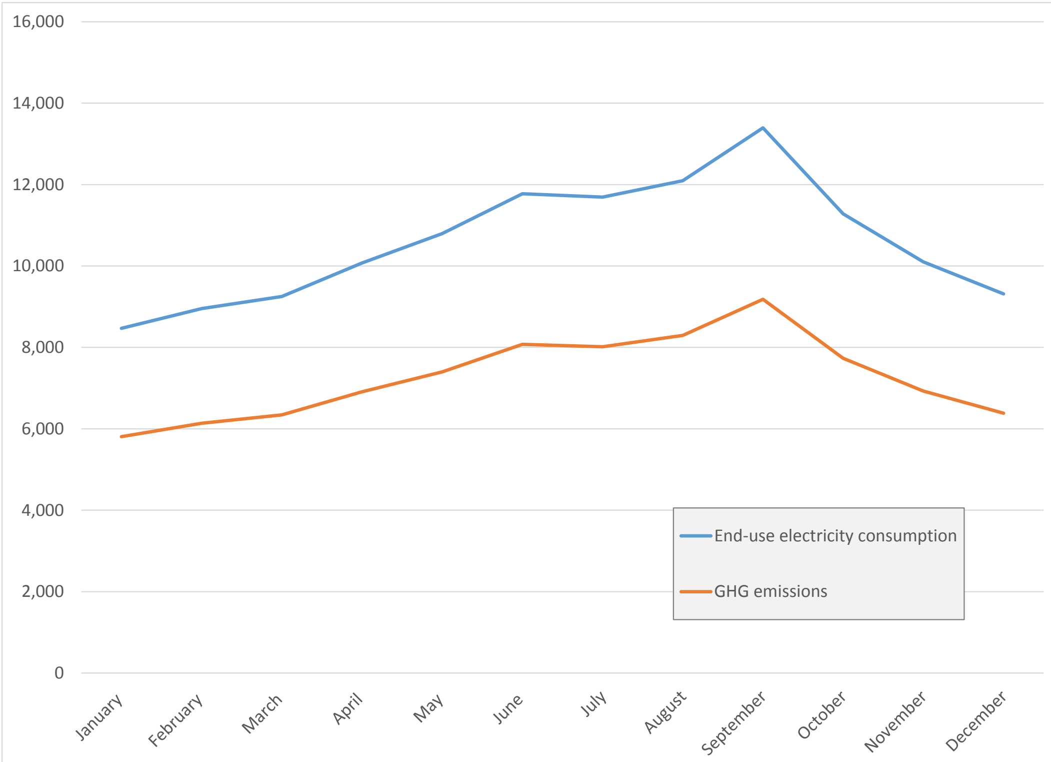
WVU-billed natural gas consumption data, summed over its 186 accounts, were provided by Dominion Hope. In 2012, WVU consumed 114,540 Mcf of natural gas, which is just over 8% of total consumption of natural gas in Morgantown (See Table 5) (Solomon, 2013 and Morris, 2014b). WVU's natural gas consumption emitted 6,258 MT CO_2e in source-based emissions and 7,702 MT CO_2e in activity-based emissions.[12] Figure 29 shows WVU's natural gas consumption and associated emissions, by month, for 2012.

The Morgantown Energy Associates power plant—located within the city limits and described in Section 2.1.2—produces electricity for the grid and steam that is used to heat a large number of WVU buildings. This combined heat and power plant is much more efficient than traditional coal-fired power plants because of its steam generation. In 2012, WVU purchased 669,805 thousand pounds of steam from the facility (Solomon, 2013). If this steam were not generated by Morgantown Energy Associates, WVU would need to heat its buildings using fuels that would emit additional GHGs.

Approximately 60% of the plant's energy output is in the form of electricity, and approximately 40% is in the form of steam. As an illustration of the GHG reduction benefits of generating steam for use by WVU, the plant emits approximately 3,500 pounds of CO_2e/MWh of electricity generated, but it emits only about 2,100 pounds of CO_2e/MWh of total energy output, including electricity and steam (USEPA, 2014g).

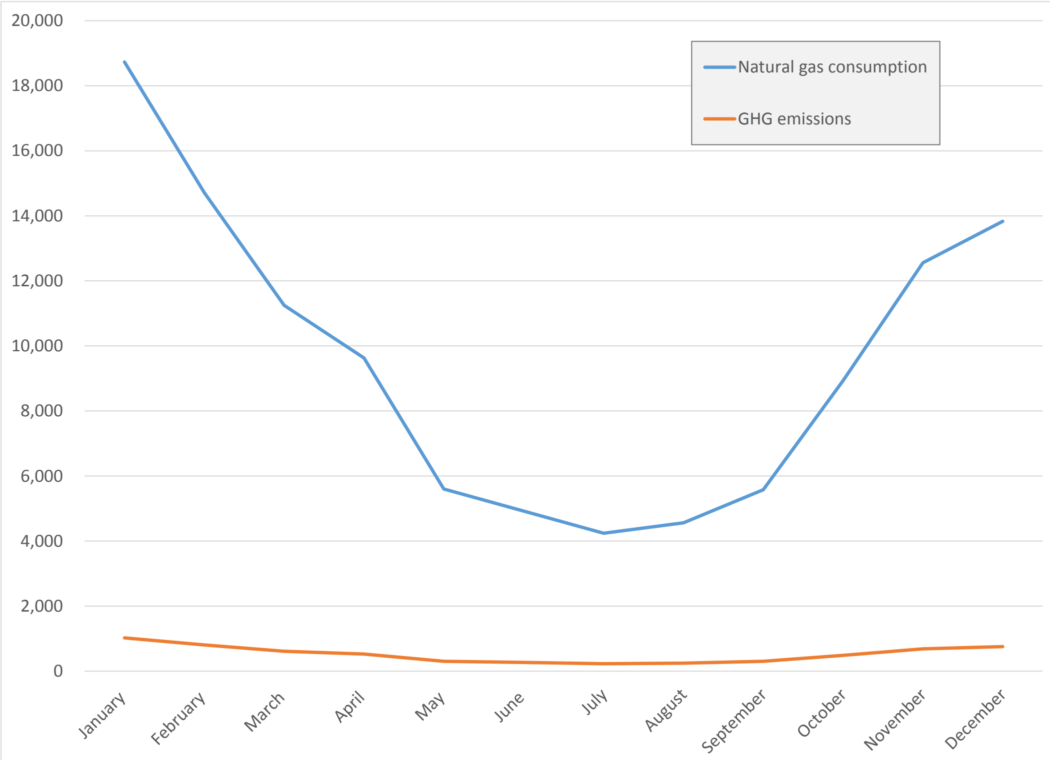
[11] Emissions are calculated using Equation 1.
[12] These emissions are calculated using Equation 4 and Equation 6.

Figure 28: Billed end-use electricity consumption (MWh) and emissions (MT CO_2e) by month for WVU (2012)



Source: Calculated in this report.

Figure 29: Natural gas consumption (Mcf) and emissions (MT CO_2e) by month for WVU (2012)



Source: Calculated in this report.

As mentioned previously in this report, MUB is the municipally owned water utility that provides service to most of the residents that live in the Monongalia County area, including WVU. A portion of the emissions detailed in Table 21 are associated with drinking water and wastewater treatment and distribution from water and wastewater services provided to WVU. Activities that contribute to water and wastewater emissions take place across the WVU campus within instruction and living facilities, but data were not available from WVU that would support calculations that would determine its share of these emissions.

Waste generated by WVU is picked up and delivered to the Republic Services transfer station by WVU staff. Just like other solid waste that is generated in Morgantown, it is then transported to the Short Creek Landfill in Wheeling. In 2012, WVU delivered 1,762 short tons of waste to the transfer station (Smith, 2014). A total of 583 MT CO_2e is associated with solid waste emissions generated from WVU operations.[13] This represents approximately 13% of emissions generated from the commercial sector and approximately 6% of overall Morgantown solid waste emissions (See Table 27).

Data that would characterize WVU's vehicle fleet, the volume of fuel consumed, and the number of miles driven in 2012 were not available for this report. Still, a portion of the emissions reported in Table 34 is associated with WVU-related travel.

[13] These emissions are calculated by applying Equation 10, Equation 11, Equation 12, and Equation 13.

7.2 Sustainability efforts

WVU is employing a number of energy conservation and sustainability programs. These programs "promote the use of sound sustainable principles and practices through learning, teaching, research, and facilities management from both an educational and operational perspective" (West Virginia University, 2014b).

The WVU Office of Sustainability has developed a systematic framework to guide, catalog, and evaluate strategic sustainability programming. Each spoke in the sustainability wheel in Figure 30 represents a specific focus area applicable to the institutional setting at WVU. Brief explanations, referenced from the Office of Sustainability's webpage, for a select number of sustainability efforts can be found below.

Figure 30: WVU sustainability framework

Ten WVU student organizations are engaged in sustainability initiatives and environmental stewardship on campus and in the community. These organizations engage in various sustainability-related activities, including repopulating trees, conducting mammal surveys, and performing energy audits for WVU facilities.

WVU has made a commitment to apply sustainable building practices and the use of alternative products that are economical while minimizing risks to human health and the environment. These efforts have included the use of vegetated (green) roofs, Leadership in Energy and Environmental Design–certified buildings, and high-efficiency campus vehicles. Facilities Management contributes to reducing building emissions by retrofitting older buildings, instituting nighttime temperature setbacks, and incorporating weatherization efforts (West Virginia University, 2014c).

WVU has implemented measures to reduce the amount of energy used on campus through conservation efforts and an ESPC with Siemens Building Solutions. This contract has resulted in significant drops in energy usage and substantial savings to WVU. In addition, WVU reduces energy consumption through the use of steam for heating and cooling. The steam is produced by the Morgantown Energy Associates power plant, a cogeneration facility located near campus. WVU also lowers energy consumption through the use of energy-efficient appliances and energy-saving technologies in many buildings (West Virginia University, 2014d).

To help divert waste from the landfill and to support the reuse of product containers, WVU has implemented a robust recycling program across all Morgantown campuses (West Virginia University, 2014e).

Furthermore, WVU Dining Services converted five facilities to tray-less dining in 2008 and 2009. The elimination of trays conserves water and reduces GHG emissions within the water and wastewater treatment and distribution sector. It also provides potential savings in natural gas or electricity, depending on how the water is heated for sanitation purposes. Other initiatives include donating excess food to local charities, donating cooking oil to a biodiesel processor, using trans-fat–free oils in fryers, switching to compact fluorescent lighting, and recycling cardboard and steel cans. WVU is currently researching local and regional product sources as well as biodegradable disposable tableware (West Virginia University, 2014f).

The Department of Transportation and Parking implements programs at WVU that promote sustainability initiatives. The department operates the Personal Rapid Transit system (Figure 31), while also offering students, faculty, and staff a variety of transportation options (West Virginia University, 2014g).

Figure 31: Morgantown's Personal Rapid Transit system

Photo credit: Wikipedia.

The department also offers incentives for the WVU community to be sustainable, including carpooling options, Zipcar access, hybrid cars, bus systems, and bicycle rental programs. In fact, through the university, all students, employees, and faculty have free access to the Mountain Line transit system (Figure 32) (West Virginia University, 2014g).

Figure 32: A Mountain Line bus in Morgantown

Photo credit: Evan Hansen.

8. STAKEHOLDER INITIATIVES

Sustainability efforts to reduce GHG emissions are largely dependent on stakeholders' willingness and ability to develop and implement successful community-based initiatives. To inform the approach of this GHG inventory and identify regionally appropriate strategies for reducing GHG emissions, the project team led a stakeholder process to introduce the overall project, identify key energy-related issues in the community, and solicit potential strategies from the community that could reduce energy use and GHG emissions.

Two public meetings were held to introduce stakeholders to the project and solicit feedback on methods, data, and reporting, while also identifying energy conservation and GHG emission reduction approaches. The first was held during a meeting of the Morgantown Municipal Green Team on November, 13, 2013. The project team presented the Morgantown GHG inventory project concept as well as very early results to the Morgantown community. As part of this event, we also facilitated a participatory activity designed to identify regionally-appropriate strategies to conserve energy and reduce GHG emissions. A voting process was employed to identify top ideas among the group while still enabling traditional brainstorming in a small-group setting. Attendees were split into three groups and asked to provide suggestions based on three different questions. Once the ideas were documented at each of the three respective stations, each attendee revisited the stations to identify and rank their top three ideas. Table 36 summarizes the top five stakeholder ideas for each question.

Table 36: The top five stakeholder ideas for each question

Question	Top five stakeholder ideas
What can you do in your home or business to reduce GHG emissions and improve energy efficiency?	1. Better insulation 2. Adopt solar energy 3. Eat less meat 4. Conserve water so less electricity is used for treatment and distribution 5. Grow more trees
What can the City of Morgantown do to reduce GHG emissions and improve energy efficiency?	1. Improve the transportation network 2. End urban sprawl 3. Expand the Personal Rapid Transit system 4. Ride sharing for large employers 5. Prioritize energy efficiency and low/no cost energy efficiency measures
What has been done elsewhere (other cities) to reduce GHG emissions and improve energy efficiency, which could also be applied to Morgantown?	1. Charge per pound for solid waste 2. Install solar panels over parking lots 3. Increase availability of local food 4. Improve access to large-scale alternative energy resources such as geothermal 5. Reduce dependence on automobiles

Though this workshop only resulted in an initial list of possible GHG reduction actions, this process and the outcomes helped shape a follow-up project proposal. In Phase 2, the project team will assess the energy efficiency potential that exists within the residential and commercial sectors through the implementation of common energy efficiency measures. Furthermore, the initial meeting enabled stakeholders to become more familiar with the project and contribute to project planning while the project team was able to build community support for continued stakeholder involvement.

A second public meeting, held on May 15, 2014, was organized by the Morgantown Municipal Green Team as part of their Green Night at the Library event series. The project team used this opportunity to present the near-final results of the Morgantown GHG inventory to the community. In order to inform individuals that were unfamiliar with the project, the project team provided a brief summary of the overall project, introduced the methodology, and then presented the results for each sector addressed within the inventory.

The project team initiated a stakeholder review process of the draft report on May 16, 2014. Project partners and individuals who provided raw data on behalf of their agencies or businesses were given the opportunity to provide comments and suggested edits for the draft report. All comments were received by May 22 and were taken into consideration during the process of finalizing this document.

9. CHALLENGES TO CONDUCTING COMMUNITY GREENHOUSE GAS INVENTORIES

One of the overarching goals of this project, besides calculating a GHG inventory for the Morgantown community, was to develop a model that other West Virginia communities could reference while calculating their own GHG inventories. The Community Protocol, which was referenced during this project, provides a robust GHG inventory methodology and contains a significant amount of flexibility. However, it can be somewhat complicated and hard to follow. We hope that this project will provide other West Virginia communities with a good example of how to apply the methodology using similar datasets.

One challenge, which can easily be eliminated, involves ICLEI membership and associated technical support. The City of Morgantown is not an ICLEI member, which means we were unable to take advantage of the technical support offered by that organization. Membership would have added efficiency to the project through direct communication with protocol experts. This membership would have also provided access to the Clean Air & Climate Protection software, which is a GHG accounting package specifically designed to support climate action planning (ICLEI, 2014b).

Another major challenge, which is not to be taken lightly, involves data availability and completeness to support the inventory. The data required to complete a community-based GHG inventory is substantial and requires the participation of a numerous partners both within and outside of the community. Table 37 summarizes the types of data that would ideally be available from partners for a fine-grained calculation of GHG emissions using the Community Protocol.

We suggest that communities start to identify and organize datasets well before they embark on the inventory process. Having a good understanding of what data are available and what data needs to be collected will improve the efficiency and results of the project.

As GHG inventories become more common, professionals in the community planning and governance fields may begin to implement strategies to address these challenges. For instance, in January 2013, the California Governor's Office officially recommended that California local governments follow the Community Protocol when undertaking their GHG emissions inventories (Knapp, 2013).

Community-focused GHG inventories are quickly becoming the standard, as opposed to inventories focused solely on local government operations or individual entities. To date, many of the inventories that have been completed, although useful for local decision making, do not follow a standard protocol, which makes it difficult to compare the results across regions or to similar communities. ICLEI's Community Protocol represents the first national standard that establishes requirements and recommended best practices for developing community-based inventories (ICLEI, 2012a).

The project team referenced the Community Protocol throughout this project, which proved to be an invaluable resource in that it provided requirements and calculation methodologies for each GHG-generating activity. Yet, challenges were experienced throughout the project. We provide an overview of those challenges by sector below.

Table 37: Partners and types of data

Partner	Type of data
Electric utility	Electricity sales by category Total generation and emissions for in-boundary generation sources
Natural gas utility	Natural gas sales by category Information detailing delivery infrastructure
Other stationary fuel distributor	Total volume of each fuel delivered by sector Number of customers for each fuel provided
Water and wastewater utility	Population served Electricity consumption by process Total number of gallons treated by process Detailed information on treatment systems and supporting infrastructure
Solid waste management entity	Information on landfills that are located in-boundary Volume of solid waste generated within the community Information on collection and disposal of solid waste Waste characterization data
Transportation management and planning entity	Output of a regional travel demand model Vehicle distance traveled within the jurisdiction Vehicle miles traveled by transportation class Fuel purchases within the region Detailed information on the regional vehicle fleet
Local government	Electricity bills for all meters Natural gas bills for all meters Water and sewer service bills Volume of solid waste generated by department/building Gasoline and diesel fuel bills for all vehicles Miles driven per year for all vehicles
Local university (if applicable)	Volume of solid waste generated by department/building Gasoline and diesel fuel bills for all vehicles Miles driven per year for all vehicles

9.1 Built environment

Data to support electricity and stationary fuel consumption calculations for the whole community were provided by FirstEnergy and Dominion Hope. These data were organized into residential, commercial, and industrial classes for electricity and natural gas.

Additional data provided by the City and WVU provided more detail on their energy consumption and were organized by month. The City was able to provide data for some, but not all, buildings by month; WVU provided monthly data but was unable to provide data on specific buildings.

Additional information is helpful when exploring activities that result in the production of emissions, but the lack of consistency across all built environment datasets presented a challenge. Under a perfect scenario, monthly electricity and stationary fuel data from the utilities, the City, and WVU would have allowed us to compare and report energy use and resulting GHG emissions in a more consistent manner.

Another challenge was experienced while exploring stationary fuels other than natural gas—which includes fuels such as coal, wood, LPG, fuel oil, and kerosene used in residential applications. Unlike natural gas, which is delivered by one company through a pipeline, other fuels are delivered by more than one company and by truck. The Community Protocol recognizes that collecting these data may be difficult and offers an alternate method to estimate the use of these other fuels within the residential sector. This method uses data from the American Community Survey on the number of residential units using certain types of fuels within a region. We then used data from the US Energy Information Administration to estimate annual energy use per residential unit for each fuel. Because this calculation methodology is based on regional averages, it likely does not precisely reflect fuel use within the city of Morgantown. Still, it is the best method available at this time.

Upstream electricity and natural gas emission factors, which represent regional or national averages, add uncertainty to the results as they do not account for local extraction methods. On the other hand, infrastructure to distribute energy is highly interconnected and is part of a larger system where energy resources intermix, making it difficult to identify what method was used to extract the resource and its origin. Due to these factors, these regional and national upstream conversion factors represent the best available data at this time.

9.2 Drinking water and wastewater

Challenges experienced while calculating GHG emissions from drinking water and wastewater treatment and distribution arose because the service areas extend beyond city limits. This meant that only a portion of emissions from water and wastewater treatment and distribution emissions result from activities taking place within Morgantown. Furthermore, the fluctuation of daily population within Morgantown adds another level of complexity when attempting to scale down total emissions to emissions associated with activities within city limits. Our estimates are conservative; for future inventories, estimates could be improved with additional data detailing the city's population fluctuations.

Another challenge involved the lack of data detailing the water distribution and wastewater return infrastructure. We were able to obtain electricity data for each lift and booster station, but data detailing directional flow and linkages within the area served by each individual lift and booster station would have addressed some of the uncertainty associated with our estimates.

While it likely represents a small overall portion of emissions associated with wastewater treatment, considerable uncertainty exists with methodologies that characterize fugitive emissions associated with wastewater treatment. These methodologies were previously designed to predict national-level emissions where detailed data on individual treatment facilities would be difficult to obtain, and therefore were developed to use population data as inputs (ICLEI, 2012c). Working with MUB to better understand specific treatment processes associated with the Star City wastewater treatment facility would be advised for future updates to this inventory.

9.3 Solid waste

The project team recognized the existence of and attempted to estimate emissions from the abandoned and capped landfill within city limits. Unfortunately, data to support these calculations, including landfill dimensions, volume of waste deposited over time, and types of waste deposited were unavailable from the City or from the West Virginia Department of Environmental Protection (WVDEP). Even though the landfill was capped in 1998, GHG emissions are being currently being produced and will continue to be produced into the future. Emissions from closed landfills, however, decline significantly over time.

Since the old landfill was capped, Morgantown's solid waste has been sent outside of city limits. Republic Services provided data detailing the volume of solid waste generated within the Morgantown community in 2012. The data were reported by residential, commercial, and mixed residential and commercial classes. The mixed residential and commercial class represents waste that is deposited in rolloffs, which are large 30-yard dumpsters that Republic Services offers to its customers. Unfortunately, Republic Services cannot provide information on the breakdown of residential versus commercial waste in rolloffs. If these data were available, tonnage from rolloffs could have been attributed to the appropriate class, which would have provided a clearer picture of waste generation sources within Morgantown. Also, if all of the city's waste was clearly divided between residential and commercial classes, separate emission factors for each of these classes could have been used.

Data on construction and demolition waste generated within Morgantown were also provided by Republic Services. Construction and demolition waste produce GHG emissions; however, these emissions are much lower than those associated with municipal solid waste. The Community Protocol does not provide a calculation methodology for construction and demolition waste, so it was not included in this report.

9.4 Transportation

Modeling transportation is a very complex exercise that utilizes a significant amount of data and complicated techniques to predict travel demand over community road networks. Currently, MMMPO, which is responsible for transportation planning in Morgantown and Monongalia County, is not required to model emissions from mobile sources because local air quality meets National Ambient Air Quality Standards.

MMMPO uses consultants to provide support for other modeling and regional transportation planning. Modeling approaches to support planning activities does not necessarily provide data that would support the estimation of GHG emissions from mobile sources. We used county-level VMT data provided in the MMMPO Long Range Transportation Plan in our calculations, which were the best data available, but VMT data at the city level would have been ideal.

Other methods that the project team researched included a calculation methodology that uses fuel purchases within the community to estimate mobile GHG emissions. These methodologies, howver, are better suited for national- or state-level inventories.

At this time, using county-level VMT and vehicle registration information was the best available method to estimate emissions from mobile sources in the Morgantown area. Until MMMPO or other entities are required to model air quality, including mobile sources, it will be difficult to estimate emissions associated with the transportation sector with great certainty.

10. CONCLUSIONS, RECOMMENDATIONS, AND NEXT STEPS

10.1 Conclusions

This study inventoried community GHG emissions for the city of Morgantown in 2012. This inventory can be used to identify energy conservation and GHG reduction strategies and can be used as a baseline, against which new policies and projects can be measured. GHG emissions were calculated for the following sectors:

- built environment (electricity, natural gas, and other stationary fuels);
- drinking water and wastewater;
- solid waste; and
- transportation.

While activity-based emissions were calculated for each sector, source-based emissions were only calculated for the built environment (Table 38). Emissions associated with community "activities" generated 805,694 MT CO_2e in 2012, while emissions associated with community "sources" generated 691,573 MT CO_2e.

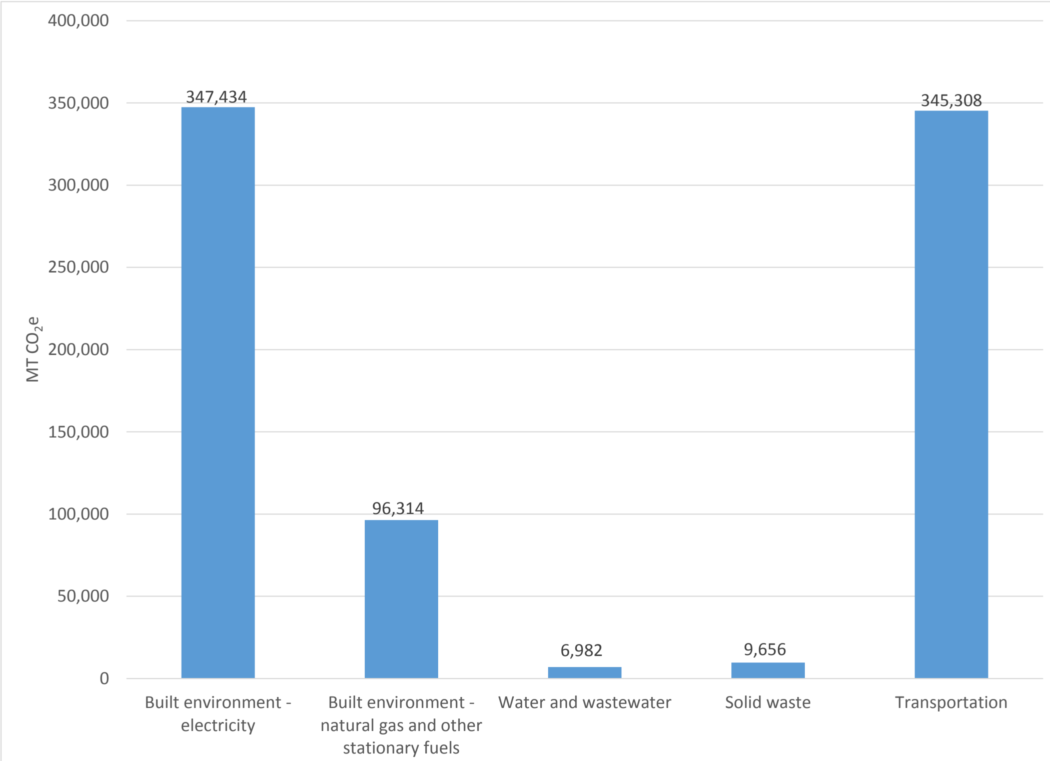
Table 38: Summary of source- and activity-based emissions (MT CO_2e)

Sector	Source-based	Activity-based
Built environment		
Electricity	613,298	347,434
Natural gas and other stationary fuels	78,275	96,314
Subtotal, built environment	**691,573**	**443,748**
Water and wastewater	N/A	6,982
Solid waste	N/A	9,656
Transportation	N/A	345,308
Total	**691,573**	**805,694**

Source: Calculated in this report.

Figure 33 shows activity-based emissions for the city of Morgantown by sector. Electricity use within the built environment sector and the transportation sector each contributed approximately 43% of total GHG emissions. Natural gas and other stationary fuels within the built environment sector represents 12% of total GHG emissions, while water and wastewater and solid waste contribute less than 1% of the city's total activity-based emissions.

Figure 33: Total activity-based emissions (MT CO_2e, 2012)



Source: Calculated in this report. Note: Water and wastewater emissions from electricity usage were subtracted from emissions in the electricity sector to avoid double counting.

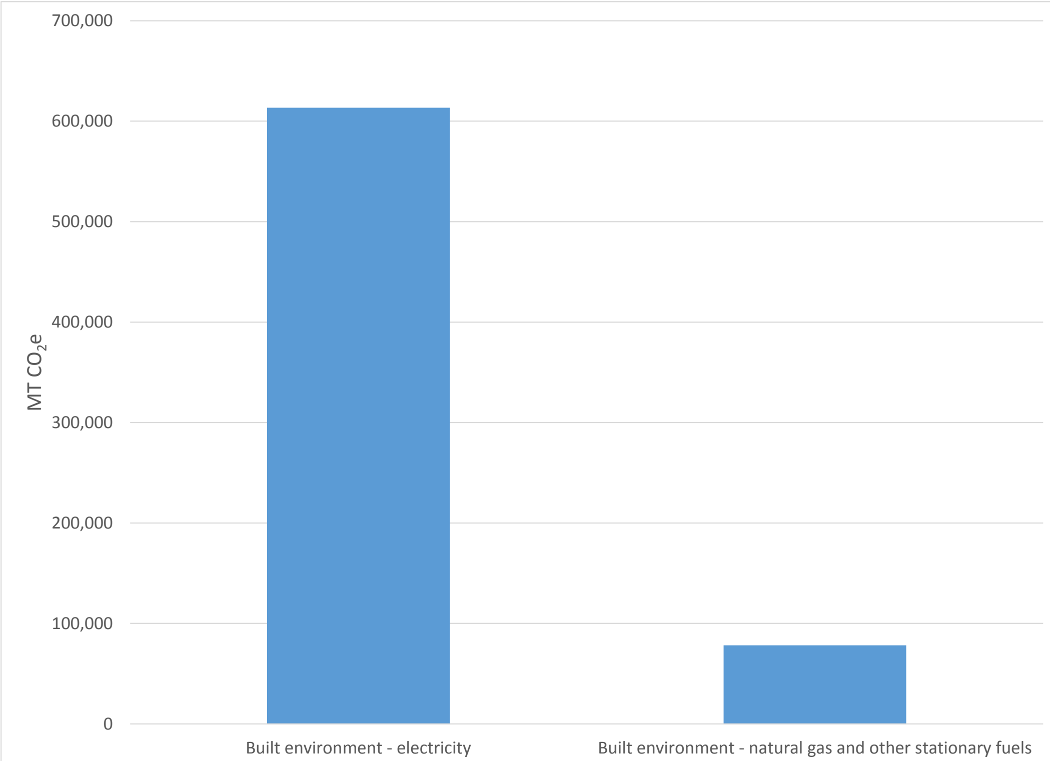
Figure 34 shows source-based emissions for the city of Morgantown. Source-based emissions were not calculated for the solid waste and transportation sectors (see Sections 4 and 5 for more details). The majority of source-based emissions calculated in this report are generated at the Morgantown Energy Associates power plant. The plant's 613,298 MT CO_2e of direct emissions released within the city limits support steam delivery to WVU as well as the delivery of electricity to the grid.

As mentioned in Section 1.1, issues with double-counting arise if source- and activity-based GHG emission results are added together and reported as a total. This is why we report these emission categories separately. Yet, the magnitude of emissions generated from the Morgantown Energy Associates power plant, as compared to total activity-based emission results, is significant. As detailed in Table 38, source-based emissions from the Morgantown Energy Associates power plant are approximately three-quarters of total activity-based emissions calculated in this report.

This GHG inventory has identified and estimated baseline emission levels across major emission-generating activities in Morgantown. Performing a GHG inventory is an important first step as it provides communities with information that can be used to inform further action. Next steps might include developing a climate action plan or an energy conservation plan using this inventory information to direct policy and to measure success.

Community-focused GHG inventories can also provide stakeholders with valuable information that they can use to modify behaviors that can save money, reduce energy use, and reduce GHG emissions. This inventory has identified the two most important opportunities for GHG reductions in the Morgantown community: electricity use in the built environment and transportation. Easy actions might include turning off lights when not needed, changing to light bulbs that use less electricity, or driving more fuel-efficient vehicles.

Figure 34: Total source-based emissions (MT CO_2e, 2012)



Source: Calculated in this report. Note: Source-based emissions from the solid waste and transportation sectors were not calculated.

For source-based emissions, the Morgantown Energy Associates power plant should be the focus of efforts to reduce GHG emissions within the city limits. Although the local community and government do not directly control operations at the power plant, options can be explored that could influence electricity production and emission levels. In June 2014, USEPA proposed its Clean Power Plan rule, which requires GHG emission reductions from existing coal-fired power plants. This rule identifies four options: (1) heat rate improvements at individual power plants; (2) substituting generation from less carbon-intensive power plants such as natural gas units; (3) substituting generation from low- or zero-carbon generation such as solar, wind, or nuclear; and (4) implementing demand-side energy efficiency (USEPA, 2014h).

10.2 Recommendations

This GHG inventory is important because it identifies GHG reduction opportunities and contains a large amount of information that can be leveraged by the Morgantown community to develop policies and programs to reduce GHG emissions. We recommend that the information contained within this report be referenced as the community and policy makers consider options. Besides energy conservation benefits that could be achieved by targeting sectors that consume large amounts of energy, non-energy benefits could also be realized through the same programs and policies. These additional, non-energy benefits include improved human health through reductions in air pollution as well as community economic benefits because Morgantown would be a more attractive place to live.

This 2012 baseline inventory represents a major first step, showing leadership and accountability in regards to climate impacts and energy use within the Morgantown community. We believe that this represents the first community GHG inventory within the state but recognize that it will provide the most value if it is updated over time to measure future success. We therefore recommend that this inventory be updated over the next three-to-five years. Furthermore, information to support these updates should be collected continuously across the Morgantown community and should take into account the data lessons learned to limit gaps and increase consistency across the data (See Chapter 9). City departments, WVU, and utilities should submit data to a community-identified organizing body. In Morgantown, a likely choice to manage and analyze these data would be the Morgantown Municipal Green Team.

USEPA recommends that local governments consider the complete set of energy and non-energy benefits of any program or policy that is developed to reduce GHG emissions. These efforts should focus on cost-effective measures that provide multiple energy, environmental, and economic benefits. We recommend that local communities prioritize efforts that provide benefits across all three categories. Finally, local communities should build stakeholder support for any climate- or energy-related policy or program throughout the development and implementation efforts (USEPA, 2014i).

In order to establish community buy-in, we recommend that any energy conservation and GHG reduction goals be developed through a community-wide participatory process. Identified goals should be referenced and published in future comprehensive plans and transportation plans. The City might also assess how new building and development standards influence community GHG emissions and energy use, in order to justify new policies and programs that support community goals.

Despite the lack of significant state support, many local governments and organizations across the state are taking actions to conserve energy and reduce GHG emissions. We recommend that communities consider establishing their own community GHG inventories that can be used to develop and measure the success of established and new programs and that these communities share their challenges and successes in an effort to improve the process and show positive steps toward climate action planning within West Virginia.

10.3 Next steps

This baseline GHG inventory was the first phase of a broader three-phase project to identify energy-saving opportunities in Morgantown that, when implemented, will save money, reduce GHG emissions, and show progress toward initiatives that the City of Morgantown supports.

Phase 2, which has been funded by the Appalachian Stewardship Foundation and will be completed in May 2015, will quantify opportunities for residents and businesses to reduce energy consumption and associated GHG emissions.

It involves performing an energy efficiency potential study that will characterize housing diversity and associated energy use across Morgantown neighborhoods. It will also use focused energy assessments, surveys, community meetings, and other available data to quantify GHG reduction opportunities that common energy efficiency measures and renewable energy systems such as solar could provide.

The inventory data contained in this report has helped identify the significant opportunity that exists within the residential and commercial sectors to reduce energy consumption, which will save money and will inevitably reduce GHG emissions. Furthermore, the GHG inventory baseline data will allow us to quantify the benefits associated with energy efficiency policy scenarios that we will explore during Phase 2.

Table 2 and Table 5 show that approximately 19% of electricity and 47% of natural gas consumption, respectively, within Morgantown was associated with the residential sector. This produced 109,427 MT CO_2e during the 2012 baseline year.

These tables also show that the commercial sector accounted for almost 80% of electricity use and slightly more than 47% of natural gas consumption. This equates 321,325 MT CO_2e released in 2012.

As we explore efficiency opportunities in the residential sector, our conduit will be the well-developed network of neighborhood associations that currently exist within the city. We aim to provide actionable information and analysis that quantifies the potential cost savings associated with simple, low-to-no-cost upgrades within homes. We will focus on efficiency measures associated with space heating and cooling, water heating, and lighting, because these systems account for over 75% of average US household energy use (USDOE, undated(b)). Focusing on home energy use also provides an opportunity to engage a larger number of individuals, creating a critical mass around energy conservation and subsequent GHG emission reductions.

Regarding the commercial sector, Downstream Strategies, in partnership with WVU, has completed over 50 energy audits for Morgantown businesses. This prior work, which we can draw from immediately, provides a robust dataset on the benefits that the implementation of recommended energy efficiency measures could provide to local businesses, including energy savings, payback periods, and GHG reductions.

We will present these data to local business associations to increase awareness about the opportunities that exist to reduce operational costs associated with energy consumption and GHG emissions.

Solar opportunities will be presented to both the residential and commercial sectors as part of the suite of measures that we will explore. The ability of solar systems to hedge against rising energy costs and their ability to offset coal-fired power plant GHG emissions will be a focused theme. Other major components of this effort will involve educating the community, assessing feasibility, and providing payback analysis examples.

The results of the Phase 1 GHG inventory and the examples listed above highlight the potential that exists within the city to reduce energy use and GHG emissions.

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