Albemarle County, Virginia

2018 Greenhouse Gas Emission Inventory Report

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Published on September 1, 2021

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Executive Summary

In a resolution on October 16, 2019, the Albemarle County Board of Supervisors adopted community-wide greenhouse gas emission reduction targets: **reduce emissions by 45% from 2008 levels by 2030 and achieve zero net emissions by 2050**. The 2018 Greenhouse Gas Emission Inventory Report provides a standardized accounting of community-wide greenhouse gas emissions based on available data from the year 2018. This inventory builds on past inventories to allow for an evaluation of progress made towards the emission reduction targets. It will also provide a new benchmark to assess future progress on the County's commitment to reduce emissions. Further, it will serve to better inform community members and elected and appointed officials on the sources and volume of greenhouse gas emissions resulting from emission-producing activities within our community. Albemarle County's Climate Action Plan, adopted by the Board of Supervisors in 2020, commits the County to complete a community-wide greenhouse gas emission inventory every two years, starting with the year 2018.

What Is a Greenhouse Gas Emission Inventory?

A greenhouse gas emission inventory is a method used by governments and other organizations to quantify their contribution to global climate change by estimating the amount of greenhouse gas emissions that result from activities or processes within the community or organization. In developing this inventory, we have followed the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC)—a set of standards developed specifically for local governments.[1]

Greenhouse gas emissions are calculated by multiplying local *activity* data by *emission factors*. Examples of activities include driving an automobile, using electricity in a building to power lights, or burning natural gas on a gas stove. Emission factors reflect the quantity of various greenhouse gasses emitted per unit of activity. The resulting product reflects the greenhouse gas emissions associated with that activity.

Most activities, especially those involving the combustion of fossil fuels, generate quantities of several significant greenhouse gases—primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Each of these contributes to global warming with varying intensity, referred to as a *global warming potential* (GWP). To provide a single number that can be compared easily over time, we use the global warming potential to convert the total of each greenhouse gas into an equivalent amount of carbon dioxide, reported as *metric tons of carbon dioxide equivalent* units (tCO_2e).

What This Inventory Includes

We calculate greenhouse gas emissions based on four standard categories of emission-producing activities, commonly referred to as sectors. Our calculations can be downloaded from Albemarle County's Climate Protection Program webpage.

[1] World Resources Institute, C40 Cities, and ICLEI Local Governments for Sustainability, *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities* (World Resources Institute, 2014), https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf.

Transportation

Our inventory accounts for emissions from vehicle travel on all public roads in Albemarle County. It does not include emissions from off-road vehicle use (e.g., farming equipment, lawnmowers), aviation, railroads, or waterborne transportation.

Stationary Energy

Our inventory accounts for the emissions associated with heating, cooking, and electricity use in buildings, as well as powering streetlights operated on behalf of the County.

Waste

The inventory accounts for methane emissions from landfills due to the decomposition of organic matter that is generated within the county.

Agriculture, Forestry, and Other Land Uses (AFOLU)

The inventory accounts for emissions associated with raising livestock, including enteric fermentation and manure management. It does not include other emissions associated with conventional agricultural practices, forestry, or other land uses.

Where Does Our Data Come From?

We use activity data for the above sectors collected by various federal, state, and regional agencies. For the Transportation sector, we use data from the Virginia Department of Transportation, supplemented by information from the US Department of Transportation, US Department of Energy, and the US Energy Information Administration. For the Stationary Energy sector, we use data provided by electric and gas utilities that serve Albemarle County, as well as data from the US Census Bureau. For the Waste sector, we use local data on solid waste reported by the Thomas Jefferson Planning District Commission (TJPDC). For agricultural emissions, we use data from the US Department of Agriculture.

We obtain emission factors and global warming potentials from the US Environmental Protection Agency (EPA), the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*, and ICLEI-Local Governments for Sustainability USA.

Due to limitations on available activity data, we do not account for emissions from every greenhouse gas-producing activity that can be included in the sectors listed above. As additional data and methods become available, we may expand the scope of emissions accounted in future years.

Results Overview

Community Emissions

We estimate total 2018 community-wide greenhouse gas emissions to be **1,419,367 metric tons of carbon dioxide equivalent (tCO_2e)**.

Below, we depict the trend in community-wide greenhouse gas emissions, based on all previous inventories developed by Albemarle County (in years 2000, 2006, 2008) and this 2018 inventory.

We also show a projection of reductions required to meet Albemarle County's 2030 and 2050 emission reduction targets.

Figure 1: Emissions over Time and Future Targets

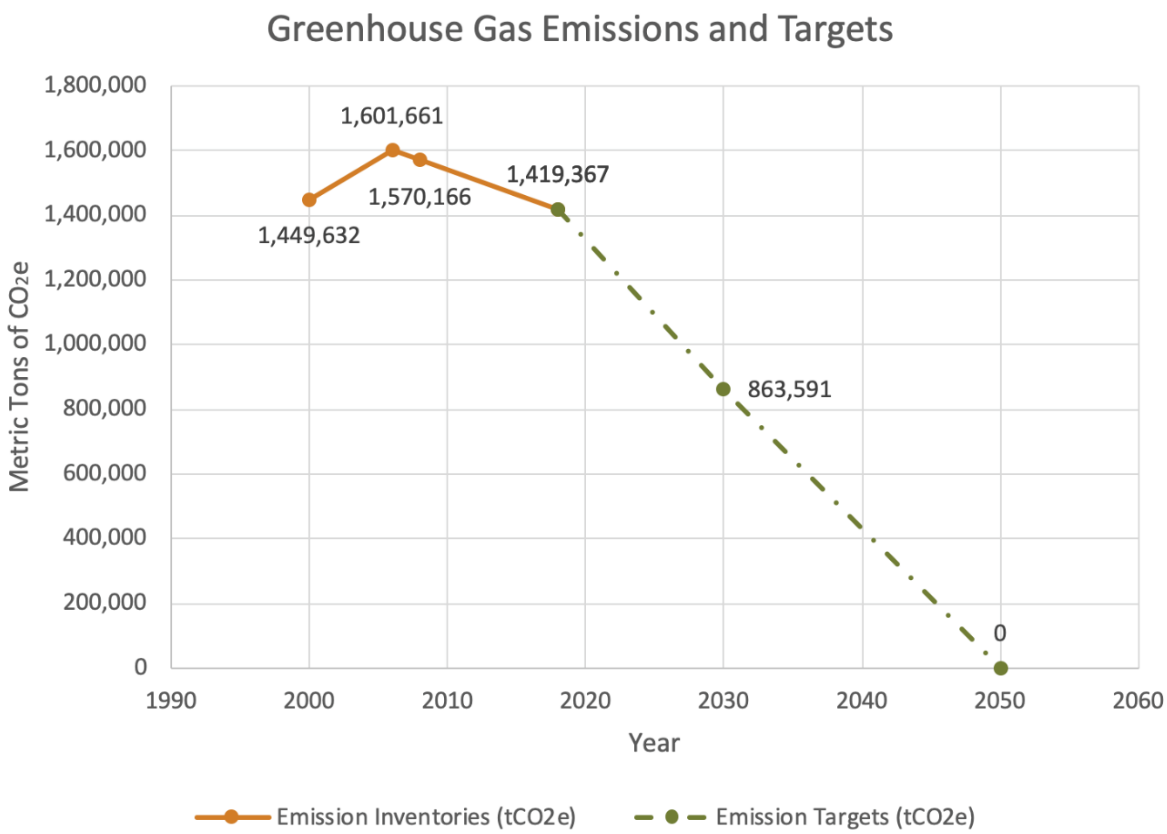


Figure 1 illustrates that community emissions have decreased over the last decade. On average, emissions have decreased by approximately 1% each year since the baseline year of 2008. Despite this progress, at this rate the community is not on track to meet the 2030 emission reduction target. To do so, the community must decrease emissions by an average of just over 4% each year through 2030.

Table 1: Comparing Total and Per Capita Emissions over Time

Year	2000	2006	2008	2018	*2030**
Emissions (tCO_2e)	1,449,632	1,601,661	1,570,166	1,419,367	*863,591**
Population[2]	83,532	93,852	97,081	108,377	*125,718**
Per Capita Emissions (tCO_2e)	17.4	17.1	16.2	13.1	*6.9**

**Future projections. 2030 population estimate based on Weldon Cooper Center for Public Service. Emission target based on 45% reduction from 2008 emission total, which reflects the County's 2030 emission reduction target.*

[2] **For 2000, 2006, and 2008:** United States Census Bureau, "Intercensal Estimates of the Resident Population for Counties: April 1, 2000 to July 1, 2010," Virginia, County Intercensal Tables: 2000-2010, accessed February 23, 2021, https://www.census.gov/data/tables/time-series/demo/popest/intercensal-2000-2010-counties.html. **For 2018:** United States Census Bureau, "Annual Estimates of the Resident Population for Counties: April 1, 2010 to July 1, 2019," Virginia, County Population Totals: 2010-2019, accessed February 23, 2021, https://www.census.gov/data/tables/time-series/demo/popest/2010s-counties-total.html. **For 2030 estimate:** Weldon Cooper Center for Public Service, "Virginia Population Projections," Demographics Research Group, accessed February 23, 2021, https://demographics.coopercenter.org/virginia-population-projections/.

Community emissions decreased despite a population increase of almost 12% between 2008 and 2018 (see Figure 2). Emissions *per capita*—or average emissions per resident—actually decreased by about 19% over this period. This decrease was not due to a reduction in the amount of *activity*. In fact, the two activities responsible for most of community emissions—on-road travel and electricity use—both increased. The decreases in both absolute emissions and per capita emissions are predominantly due to these activities becoming more energy efficient. Examples include higher average fuel economy for vehicles and lower greenhouse gases emissions from the production of electricity.

Figure 2: Albemarle County Population and Emissions per Capita

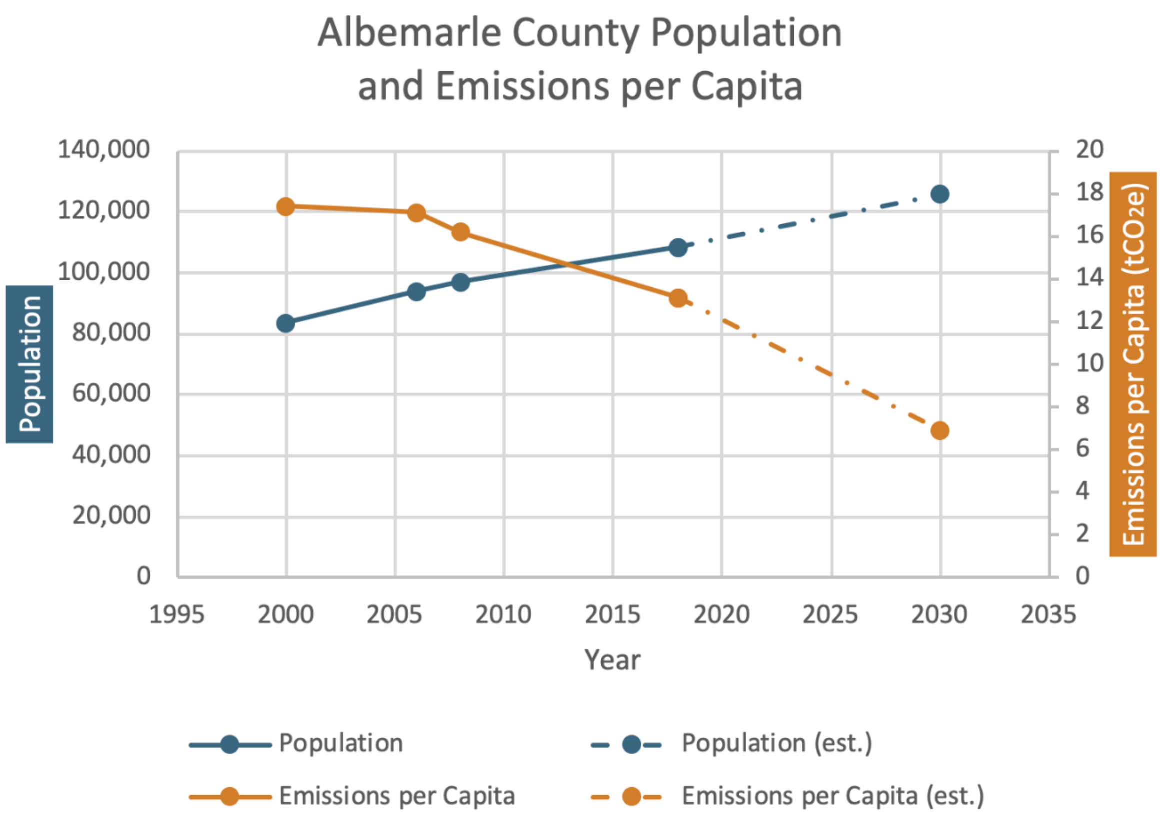


Figure 3 (below) depicts the composition of community emissions in 2018 by sector:

Figure 3: Community-Wide Emissions by Sector

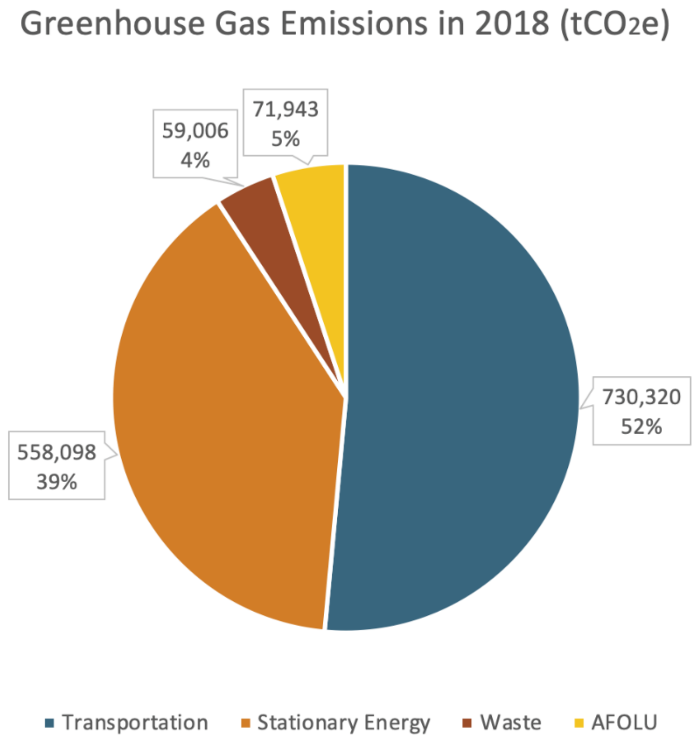
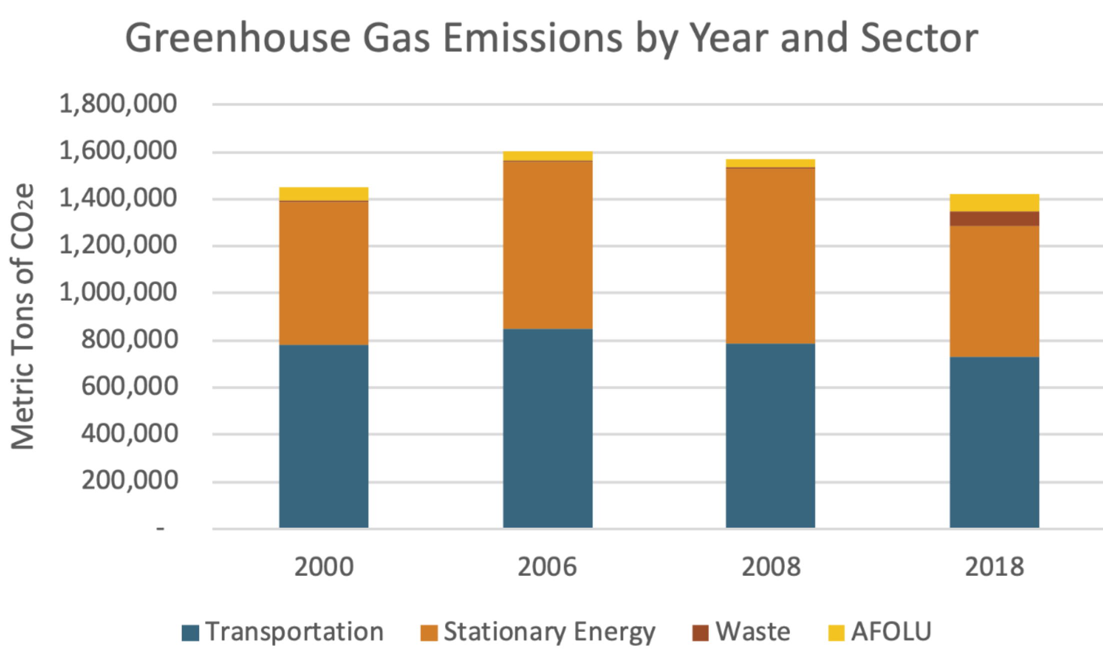


Figure 3 illustrates that the vast majority of local greenhouse gas emissions are due to transporting people and goods and powering buildings in fossil-fuel-intensive ways.

Figure 4 depicts the composition of emissions by sector for each year that the County has conducted a greenhouse gas emission inventory:

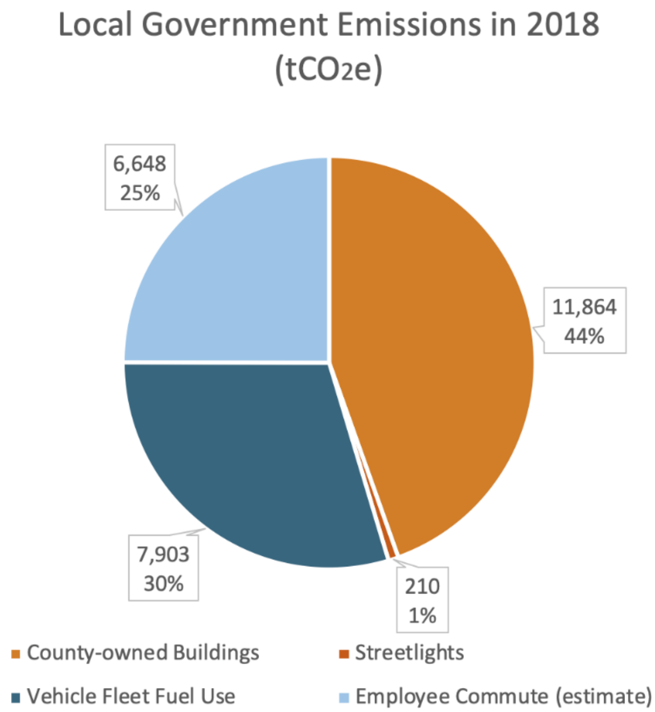
Figure 4: Greenhouse Gas Emissions by Year and Sector (tCO_2e)



Local Government Emissions

We conduct an inventory of greenhouse gas emissions for local government as a subset of the community-wide inventory to inform policy and operations. For this subset, we counted emissions that result from the operation of County-owned buildings, streetlights, and vehicles, and from the commutes of County employees. These emissions are part of the Transportation and Stationary Energy sectors.

Figure 5: Local Government and Public Schools Emissions by Source (tCO_2e)



We estimate emissions from the operations of local government and public schools to be 26,625 tCO_2e—roughly 2% of the community total. Figure 5 depicts the composition of local government emissions *by emission sector* (blue and orange coloring) and *by operational area* (individual wedges).

By our accounting, total local government emissions decreased by approximately 60% from 2008 to 2018. Changes in sources of electricity generation and in the portfolio of buildings operated by the County may explain a portion of the drop in emissions from County-operated buildings between 2008 and 2018. However, some of this reduction is likely due to methodological changes. Since we don't have sufficient details on the methods used in 2008, we emphasize the accuracy of the 2018 results and our ability to use these for comparison in future inventories.

New Metrics

For the first time, Albemarle County has utilized a new tool from ICLEI to estimate the effect of forests and trees throughout the County on greenhouse gases—particularly carbon dioxide. This tool—called Land Emissions and Removals Navigator (LEARN)—accounts for the *sequestration* of carbon due to forest growth and the *release* of carbon due to forest loss occurring over time. The analysis revealed that, on balance, forests in Albemarle County sequester significant amounts of carbon dioxide[3] (estimated to be 945,732 tCO2e per year on average) – providing a local and global benefit. See Appendix A for a discussion of this analysis.

[3] Plants and sequester carbon dioxide through the process of photosynthesis, in which the plant absorbs sunlight and carbon dioxide and converts these into sugars. Other greenhouse gases—such as methane or nitrous oxide—are not sequestered through natural processes.

Because the existence and growth of forests in central Virginia is a natural process—and not the outcome of deliberate climate action—the net carbon sequestration revealed in this analysis cannot be considered as progress made towards greenhouse gas reduction targets. Nonetheless, the magnitude of the sequestration potential of local forests, trees, and other ecosystems emphasizes the importance of protecting and sustainably managing these resources—to preserve their sequestration potential, to prevent large amounts of unnecessary emissions from forest loss, and for the many other benefits of healthy local forests.

As part of this inventory, we also develop a method for measuring the emission reductions associated with local electric vehicle (EV) use, which is not considered in the standard protocols for measuring transportation emissions. While the use of EVs does result in greenhouse gas emissions from electricity use when charging the battery, EV usage simultaneously supplants emissions that would have been produced by traditional fossil fuel-burning vehicles. The emissions per mile of an EV are about 30% that of a traditional vehicle.[4] Because only about 0.1% of Virginia-registered vehicles were EVs in 2018, the effect of EVs is relatively small right now—decreasing our community-wide emissions by 395 tCO_2e. However, this effect will grow as EVs become more mainstream over time.

Conclusions and Future Directions

Conclusions

From 2008 to 2018, community-wide emissions in Albemarle County decreased, largely due to factors outside of our direct influence, such as improvements to vehicle fuel efficiency and changes in the sources of electricity generated for the regional electric grid. Despite this decrease in emissions, the community will need to increase the pace of reducing greenhouse gas emissions for us to achieve the 2030 and 2050 reduction targets set by the Board of Supervisors in October 2019.

With the adoption of the County's first Climate Action Plan (CAP) by the Board of Supervisors in 2020, the County now has a program in place to advance a broad set of actions designed to promote community-wide emission reductions in the coming years and decades. In other words, the purpose of this CAP is to increase the pace of reducing emissions. If we are successful in implementing the CAP, we should expect to see an increase in the pace of greenhouse gas emission reductions in future inventories (following the steeper downward slope of the dashed green line in the first chart above).

Future Directions

The County's Climate Action Plan commits us to conducting greenhouse gas emission inventories every two years, starting with 2018. At this frequency, we will be better able to monitor progress and adjust our climate action work accordingly to meet our targets.

The future will also provide opportunities for us to incorporate additional emission calculations, as data and methods become available. One likely example is accounting for the sequestration of carbon dioxide by forests and other natural landscapes based on policies and programs in our

[4] US Department of Energy, Alternative Fuels Data Center, "Emissions from Hybrid and Plug-In Electric Vehicles," accessed August 12, 2021, https://afdc.energy.gov/vehicles/electric_emissions.html.

CAP—as well as emissions due to loss of such landscapes. In Appendix A, we describe a new tool we've already utilized that is focused on the greenhouse gas effect of forests and trees. This will allow us to assess the progress of actions that we take to protect and enhance the local natural environment. In addition, we will also explore data now being generated by the Virginia state government related to the effect of agricultural practices adopted by growers in Albemarle County. This data will allow us to create a more robust inventory of agriculture, which is currently limited to livestock emissions.

Introduction

In 2017, the Albemarle County Board of Supervisors committed to setting a community-wide greenhouse gas emission reduction target and to developing a Climate Action Plan with strategies and actions to reduce emissions. In a resolution on October 16, 2019, the Board of Supervisors set a community-wide greenhouse gas emission reduction target to reduce emissions by 45% from 2008 levels by 2030 and to achieve zero net emissions by 2050. On October 7, 2020, the Board of Supervisors subsequently adopted a Climate Action Plan, with the stated purpose "to guide local government actions to reduce long-term contributions to climate change throughout the community." In addition to advancing a variety of objectives and action areas to address climate change, the Climate Action Plan commits the County to conducting a greenhouse gas emission inventory every two years, starting with the calendar year 2018. Additional information and resources on the County's Climate Protection Program can be found at www.albemarle.org/climate.

The Albemarle County 2018 Greenhouse Gas Emission Inventory Report provides a standardized accounting of community-wide emissions based on available data from 2018. This inventory allows for an evaluation of progress made towards emission reduction targets and will also provide a new benchmark to assess future progress on the County's commitment to reduce emissions. It will serve to better inform community members, stakeholders, and local decision-makers on the sources and volume of greenhouse gas emissions resulting from emissions-producing activities within our community.

Through adoption of the Climate Action Plan, Albemarle County committed to completing a community-wide greenhouse gas emission inventory every two years, starting with 2018. These biennial assessments will complement past greenhouse gas emission inventories completed for calendar years 2000, 2006, and 2008, available in the *County of Albemarle, VA Emissions Baseline Report* released in 2009.

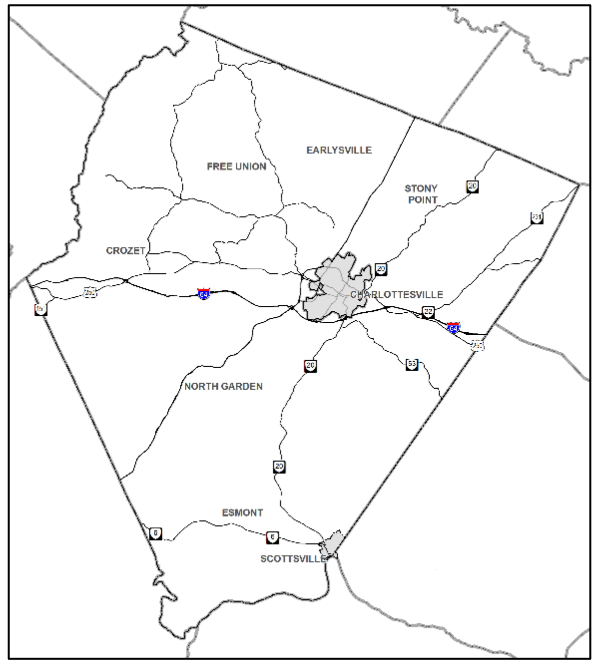
This assessment considers data at a broad scale, reporting emission totals for the entire Albemarle community. Therefore, inferences about individual companies or persons are not possible. However, due to the County's commitment to reducing our own emissions, those associated with Albemarle County government—including public schools—are reported as a subset.

Emissions totals are categorized by the following emission sectors, defined in the next section:

- Transportation
- Stationary Energy
- Waste
- Agriculture, Forestry, and Other Land Uses (AFOLU)

Within this report, we will explain the data and calculation methods used to develop this inventory. For target reporting consistency, we follow the process, scope, and scale of the 2008 baseline inventory as closely as possible. We describe any deviations from the data or processes used in the 2008 baseline in the summaries for each emission sector. We also detail any assumptions and estimates we make and provide additional information about any new metrics we introduce.

Inventory Protocols



In developing this greenhouse gas emission inventory, we have followed the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC)—a set of standards developed specifically for local governments.[5] Following this protocol, we report community emissions from greenhouse gas-producing activities that occur inside the geographic boundary of Albemarle County (see inset map) and emissions from local government activities *as a subset of* the community-wide emissions.

Because of how interconnected communities are with each other—with people, energy, and other resources constantly crossing borders—emissions *resulting from* activities in one community may be emitted outside that community. These distinctions can be acknowledged through the following GPC categories:

Scope 1	emissions from sources located within the county boundary
Scope 2	emissions occurring outside the county boundary but as a consequence of the use of grid-supplied electricity within the county boundary
Scope 3	all other emissions that occur outside the county boundary as a result of activities taking place within the county boundary

This inventory covers activities that occurred during the 2018 calendar year.

GPC Reporting Level

The *city-induced framework* of the GPC allows a locality to account for a variety of emissions associated with a community, including emissions that occur outside a community's geographic boundary as a result of *activities* that occur within that locality's geographic boundary. One example of this is a power plant outside the locality that provides electricity to meet demand inside the locality.

The city-induced framework provides two levels of reporting: BASIC and BASIC+, with the latter more comprehensive and based on data that is often more difficult to obtain. While we generally report at the BASIC level, there are some data at the BASIC level to which we do not have access, such as emissions from railways, aviation, off-road transportation, fugitive emissions from oil and

[5] World Resources Institute, C40 Cities, and ICLEI Local Governments for Sustainability, *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities* (World Resources Institute, 2014), https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf.

natural gas systems, and machinery used in agriculture and forestry. However, we also report some data at the BASIC+ level, including partial emissions data on Agriculture, Forestry, and Other Land Use (AFOLU).

Community Inventory

The community-wide inventory counts greenhouse gas emissions resulting from emission-inducing activities that take place within the geographic boundaries of Albemarle County. This includes emissions from, for example, transportation on public roads within Albemarle County's jurisdictional borders, fuel combustion in buildings within the county for heating and cooling, and electricity consumed in buildings located in the county, regardless of where that electricity is produced.

The scopes considered within each emission sectors are:

Emission Sector	Scope	Description
Transportation	Scope 1	all on-road traffic within the county boundary
	Scope 2	except electricity used to charge electric vehicles
Stationary Energy	Scope 1	onsite fuel use by buildings
	Scope 2	electricity use by buildings
Waste	Scope 1	solid waste generated and processed in Albemarle County
	Scope 3	solid waste generated in the County and processed elsewhere
Agriculture, Forestry and Other Land Use (AFOLU)	Scope 1	livestock only

Exclusions

To remain as consistent as possible with what was counted in the County's 2008 baseline inventory, and due to lack of data or activities within our geographic boundary, our 2018 inventory excludes some emission sources typically called for by the GPC.

- **Transportation:** We do not include emissions from railways, waterborne navigation, aviation, or off-road vehicles, none of which were included in previous inventories.
- **Stationary Energy:** We do not include emissions from energy industries or from fugitive emissions from mining, processing, storage, and transportation of coal or oil and natural gas systems. These activities either do not occur in Albemarle County or were not included in the 2008 baseline inventory. Stationary energy emissions from agriculture, forestry, and fishing activities are included in the categories for residential, commercial, and industrial buildings, based on how utility companies report their usage data.
- **Waste:** We do not include emissions from incineration and open burning of waste or from wastewater generated in the county, neither of which were included in the 2008 baseline inventory.
- **AFOLU:** We do not include emissions from agriculture other than livestock, nor do we include emissions from forestry or other types of land uses. In Appendix A, however, we introduce a new method for tracking carbon emissions *and* carbon sequestration resulting

from forests and changes in land use. In future inventories, we will consider the effect of purposeful carbon sequestration practices on net community emissions.

Local Government Inventory

As a subset of community-wide emissions, we report emissions produced by Albemarle County Local Government and Public Schools building operations, fleet vehicles, employee commutes, and streetlights. The local government inventory will inform improvements to local government operations and will allow us to monitor our efforts to lead by example. Note that the local government inventory is included within the total community-wide inventory.

Methodology

Basic Calculation

Greenhouse gas emissions are calculated by multiplying an *emission factor* by local *activity* data, expressed in the simplest terms as follows:

(activity) x (emission factor) = (GHG emissions)

The resulting product reflects the greenhouse gas emissions associated with that activity, which are reported in terms of *metric tons of carbon dioxide equivalent* units (tCO_2e).

The activity data consist of measured or estimated greenhouse gas-producing activities, like traveling in vehicles or using electricity. Examples of activity data include total miles traveled by vehicles, kilowatt-hours of metered electricity, and cubic feet of natural gas. In this context, activities are greenhouse-gas producing activities (from burning fossil fuels), not activity in the sense of having an active lifestyle (e.g., walking, biking).

The emission factors reflect the amounts of various greenhouse gasses emitted per unit of activity. For example, the emission factor for carbon dioxide from a gasoline-powered automobile is 8.78 kilograms per gallon; that is, for every gallon of gasoline burned to power the vehicle, 8.78 kilograms of carbon dioxide are released into the atmosphere. Emission factors differ based on greenhouse gas, fuel used, type of combustion or other chemical or biological reactions, and other variables.

Most activities, in particular the burning of fossil fuels, generate quantities of several significant greenhouse gases—primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Each of these contributes to global warming with varying intensity, quantified as a *global warming potential* (GWP). Emissions from each greenhouse gas are multiplied by the respective global warming potential to convert the total greenhouse effect into an *equivalent* effect in terms of carbon dioxide only, reported as metric tons of carbon dioxide equivalent units (tCO_2e).[6]

[6] We use the 100-year global warming potential (GWP) values for methane (CH_4) and nitrous oxide (N_2O) found in the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), based on the IPCC Fifth Assessment Report. See: World Resources Institute, C40 Cities, and ICLEI Local Governments for Sustainability, *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities* (World Resources Institute, 2014), https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf, 51.

Although the basic calculation is simple, the actual calculations are often more complicated for a variety of reasons:

- Data on activities are often reported at a national, state, or regional level, and are sometimes incomplete, requiring careful extrapolation for the county level.
- Different fossil fuels and combustion methods used in activities produce different amounts of greenhouse gas emissions, requiring the application of different emission factors.
- An "activity" sector (e.g., transportation) is actually a collection of activities that require many separate calculations, which feed into an overall total.

In presenting the results of our inventory, we offer a summary of data sources and calculation methodologies for each emission sector, with the intention that our method be transparent and reproducible.

Calculation Procedure

We calculated our 2018 inventory using two parallel procedures. First, we used the ICLEI-USA ClearPath software platform,[7] which computes greenhouse gas emissions from activity data input by users. The benefit of using ClearPath is that users must simply enter the activity data and the software performs the emission calculations. As such, many cities and counties across the United States use this software, and it has become somewhat of a standard. However, the computational method is not entirely transparent; having input activity data, the software generates aggregate emission numbers without providing step-by-step description of assumptions and intermediate calculations (e.g., unit conversions, weighted averages).

To support transparency in our reporting to Albemarle County residents and other local stakeholders, we also performed our own calculations of greenhouse gas emissions based on the same activity data, using careful application of standard emission inventory methods. Because our results are based on transparent, step-by-step calculations that cite all sources and disclose all assumptions, we have chosen to report these numbers—as opposed to those generated by ICLEI's Clearpath software—as the final values presented in this inventory. Our calculations can be found as a spreadsheet located on the County's Climate Protection Program webpage.[8] In the case of the Transportation and Stationary Energy sectors (the bulk of community emissions), the results of our calculations and the output of the ClearPath software differ by less than one percent, which increases our confidence in both numbers.[9]

Comparison to Past Inventories

Any data reflecting a point in time is most meaningful when it is compared to past data points. To better allow us to draw conclusions and predict trends, we have generally aimed for methodological consistency with the 2000, 2006, and 2008 inventories. In a few cases, however,

[7] ICLEI-USA: Local Governments for Sustainability is a membership organization for local governments that provides technical expertise and guidance for conducting greenhouse gas emission inventories, including the ClearPath software. See https://icleiusa.org/clearpath/.
[8] See https://www.albemarle.org/government/facilities-environmental-services/environmental-stewardship/climate-protection.
[9] Our result for the Waste sector differs by a larger amount due to lack of data and greater uncertainty about the values of factors in the equations for calculating waste emissions. In the case of AFOLU, we only report our calculation, which is based on a step-by-step method provided by ICLEI-USA.

we have made changes to the methodology of past years to address inconsistencies and ambiguities. These changes are described below. We hope that our careful documentation of our methods in this inventory report will support greater consistency in the future.

Local Government as a Subset of Community-Wide Inventory

In the past inventory reports (2000, 2006, and 2008), we erroneously double-counted the local government emission totals by adding them to the community-wide totals, when local government emissions are already counted within the calculations for community-wide emissions.

We correct for this methodological error in our 2018 inventory, reporting local government emissions as a subset of our community-wide inventory. We also recount and report the totals, in this document, for 2000, 2006, and 2008 according to the 2018 methodology. This recounting represents a correction of the numbers listed in the County's adopted Climate Action Plan. When revising and updating that plan, we will update the numbers.

Estimating Electric Vehicle Emissions

In order to support tracking the local adoption of electric vehicles over time, we estimate these emissions as a distinct subcategory of the Transportation sector. This is explained and quantified below. Accounting for the adoption of electric vehicles was not done in previous years.

Inclusion of "Government / Other" Stationary Energy Emissions

In our 2018 inventory, we include a category of Stationary Energy emissions labeled "Government/Other". This category includes all buildings in Albemarle County that are classified as government—including buildings owned and operated by Albemarle County as well as other governmental entities (e.g., UVA, federal, state). This inclusion reflects the fact that Government/Other—along with Residential, Commercial, and Industrial—is one of the categories reported by most electric utilities serving the county and Charlottesville Gas.

However, Government/Other was not reported or included in the total emission values for the County's 2000, 2006, or 2008 inventories. It may have been unintentionally omitted or arbitrarily included in another category. In the interest of transparency, we report a number for Government/Other for 2008 based on data we obtained, but we do not include this number in the total because it is not included in the 2008 inventory report.

We recognize that this inconsistency in counting the Government/Other category across the County's inventories creates a challenge for comparison with past inventories. In future inventories, we will continue to report and include Government/Other.

Inventory Results

Below, we report the results of our greenhouse gas emission inventory for 2018. First, we present total 2018 community-wide emissions and compare these to the emission totals of past years. We then offer more detailed examinations of results for each emission sector, including summaries of computation methodologies, comparisons to past years, and discussions of trends. Finally, we present 2018 emissions resulting from local government operations only and compare these to past years.

Community-wide Emissions

We estimate total 2018 community-wide greenhouse gas emissions to be **1,419,367 metric tons of carbon dioxide equivalent (tCO_2e)**.

Figure 6 depicts the trend in community-wide greenhouse gas emissions, based on the totals from inventory years of 2000, 2006, 2008, and 2018 (orange line). We also show a projection of reductions required to meet Albemarle County's 2030 and 2050 emission reduction targets (green dashed line).

Figure 6: Emissions over Time and Future Targets

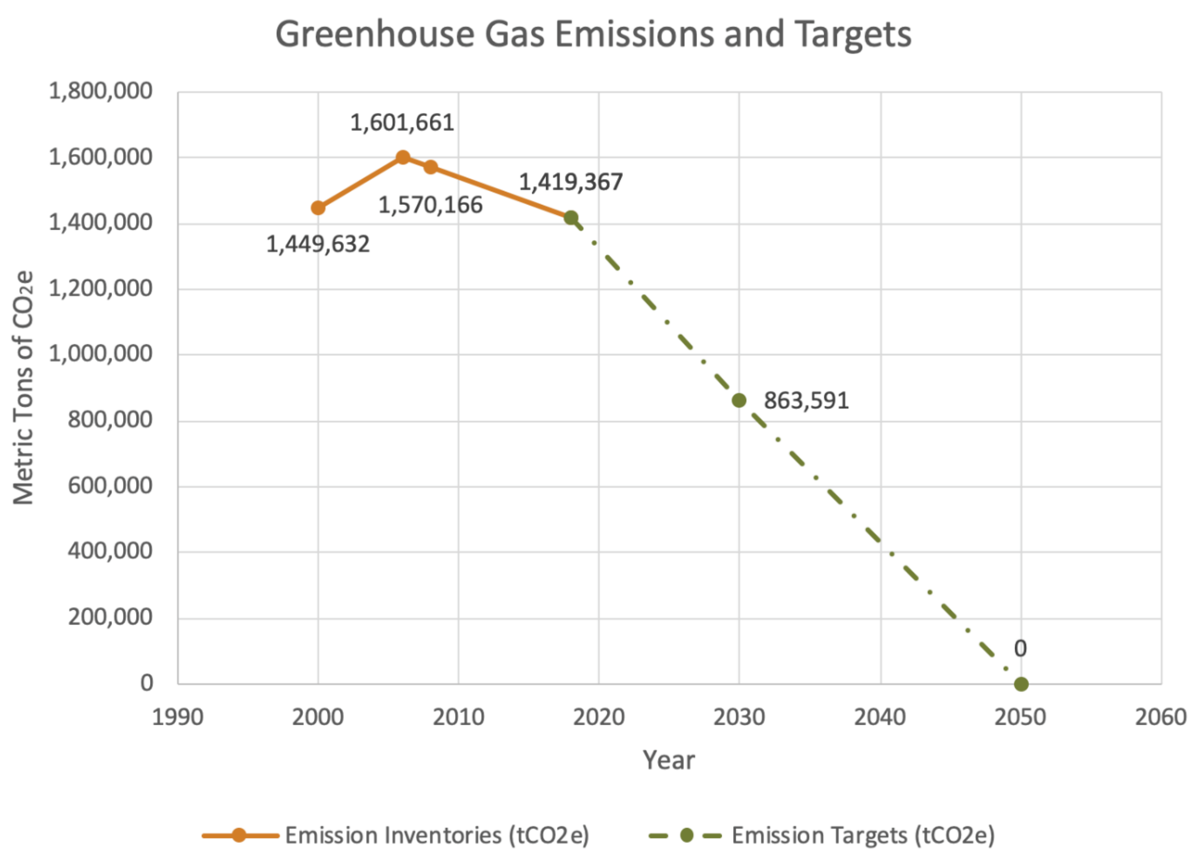


Figure 6 illustrates that community emissions have decreased over the last decade. On average, emissions have decreased by approximately 1% each year since the baseline year of 2008. Despite this progress, at this rate the community is not on track to meet the 2030 target. To do so, the community must decrease emissions by an average of just over 4% each year through 2030.

Per Capita Emissions

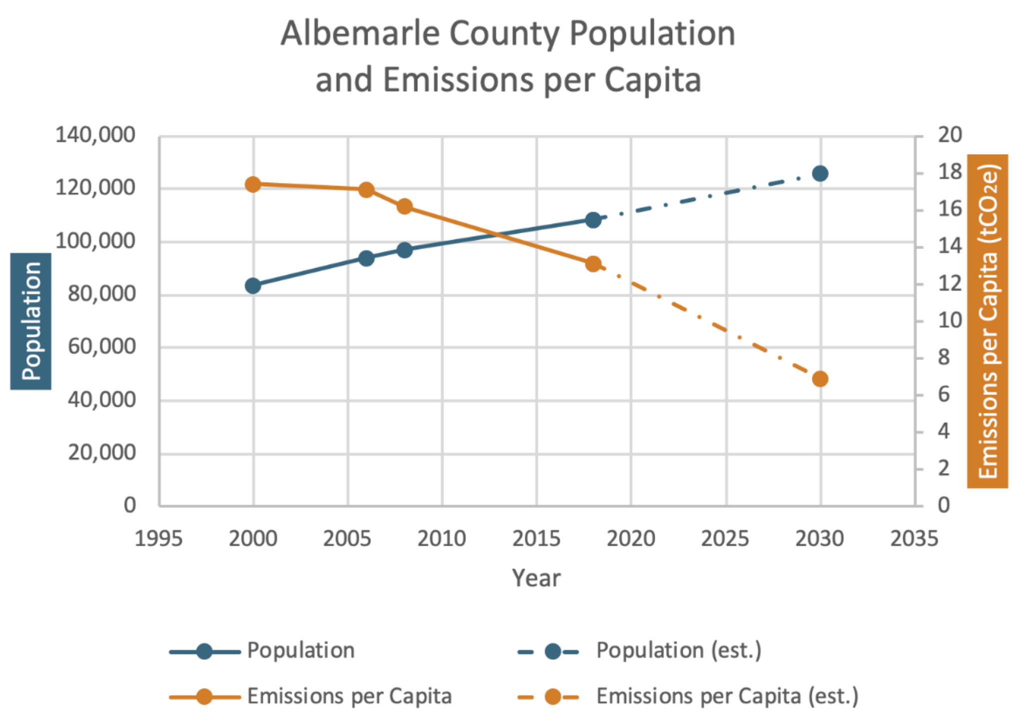
While the County's emission reduction targets were established in terms of total community emissions—ignoring any confounding effects of population growth—it may be of interest to look at the change over time in emissions *per capita*, or the quantity of emissions generated by the average resident. These emissions are summarized in Table 2.

Table 2: Comparing Total and Per Capita Emissions over Time

Year	2000	2006	2008	2018	*2030**
Emissions (tCO_2e)	1,449,632	1,601,661	1,570,166	1,419,367	*863,591**
Population[10]	83,532	93,852	97,081	108,377	*125,718**
Per Capita Emissions (tCO_2e)	17.4	17.1	16.2	13.1	*6.9**

**Future projection. 2030 population estimate based on Weldon Cooper Center for Public Service. Emission target based on 45% reduction from 2008 emission total.*

Figure 7: Albemarle County Population and Emissions per Capita



As indicated in Table 2 and Figure 7, Albemarle County's population has grown steadily over time, increasing approximately 30% between 2000 to 2018 and 12% between 2008 to 2018. So, while total emissions increased from 2000 to 2006, emissions per capita actually decreased, albeit slightly. During subsequent years (from 2006 to 2018), total emissions decreased despite a rising population. Between 2008 and 2018, total emissions dropped almost 10% while per capita emissions dropped approximately 19%.

For readers who might wonder how the average Albemarle County resident compares with the United States and other parts of the world, Table 3 presents per capita emissions in Albemarle County for the years that the County has conducted inventories alongside per capita emissions for the United States, major regional groups of countries, and the world.

[10] **For 2000, 2006, and 2008:** United States Census Bureau, "Intercensal Estimates of the Resident Population for Counties: April 1, 2000 to July 1, 2010," Virginia, County Intercensal Tables: 2000-2010, accessed February 23, 2021, https://www.census.gov/data/tables/time-series/demo/popest/intercensal-2000-2010-counties.html. **For 2018:** United States Census Bureau, "Annual Estimates of the Resident Population for Counties: April 1, 2010 to July 1, 2019," Virginia, County Population Totals: 2010-2019, accessed February 23, 2021, https://www.census.gov/data/tables/time-series/demo/popest/2010s-counties-total.html. **For 2030 estimate:** Weldon Cooper Center for Public Service, "Virginia Population Projections," Demographics Research Group, accessed February 23, 2021, https://demographics.coopercenter.org/virginia-population-projections/.

Table 3: Global Comparison of Per Capita Emissions (tCO_2e) by Year

Per Capita Emissions (tCO_2e) by Year	2000	2006	2008	2018
Albemarle County	17.4	17.1	16.2	13.1
United States	22.9	21.1	20.5	17.7
East Asia and Pacific	4.5	6.2	6.3	7.8
European Union	9.2	9.1	8.7	7.5
Latin America and Caribbean	7.8	7.7	7.8	6.2
Middle East and North Africa	5.7	6.7	7.1	7.4
South Asia	1.4	1.7	1.8	2.3
Sub-Saharan Africa	3.9	3.8	3.7	3.5
World	5.8	6.4	6.4	6.5

Source for all areas other than Albemarle County: ClimateWatch, "Historical GHG Emissions"[11]

Table 3 shows that Albemarle County has historically emitted slightly less per capita than the United States, but more per capita than other regions of the world.

• • •

In summary, we see a recurring theme for Albemarle County's inventories since 2006 in which total emissions are decreasing, despite an increase in emission-producing activities, such as driving and energy use by a growing number of buildings. While there is no single metric that represents aggregate community activity, we use population as a proxy in the Per Capita Emissions section above. The counterintuitive divergence of activity going up and emissions going down can be explained mostly by improved efficiencies—for instance, an increase in the miles per gallon of vehicles, cleaner electricity from the regional grid, and more efficient appliances and HVAC systems. These data indicate that to meet our 2030 goal to reduce emissions by 45% from 2008 levels, the community will need to put extra effort into emission reduction initiatives to overcome the expected growth in the number of individuals contributing to greenhouse gas emissions.

Community-wide Emissions by Sector

In Table 4, we report a breakdown of emissions for each sector across the four years that Albemarle County has conducted a greenhouse gas emission inventory.

Table 4: Emission Comparison by Year and Sector

Sector	2000		2006		2008		2018	
	tCO_2e	%	tCO_2e	%	tCO_2e	%	tCO_2e	%
Transportation Emissions	783,196	54.0	850,597	53.1	785,630	50.0	730,320	51.5
Stationary Energy Emissions	607,189	41.9	705,448	44.0	745,218	47.5	558,098	39.3
Waste Emissions	2,205	0.2	6,826	0.4	6,978	0.4	59,006	4.2
AFOLU Emissions	57,042	3.9	38,790	2.4	32,340	2.1	71,943	5.1
Total Emissions	**1,449,632**		**1,601,661**		**1,570,166**		**1,419,367**	

[11] ClimateWatch, "Historical GHG Emissions", accessed on August 18, 2021, https://www.climatewatchdata.org/ghg-emissions?calculation=PER_CAPITA&end_year=2018&regions=USA&start_year=1990.

Figure 8 visually depicts this emission breakdown by sector and year, and Figure 9 shows the percentage composition of total community emissions in 2018 by each sector.

Figure 8: Greenhouse Gas Emissions by Year and Sector (tCO_2e)

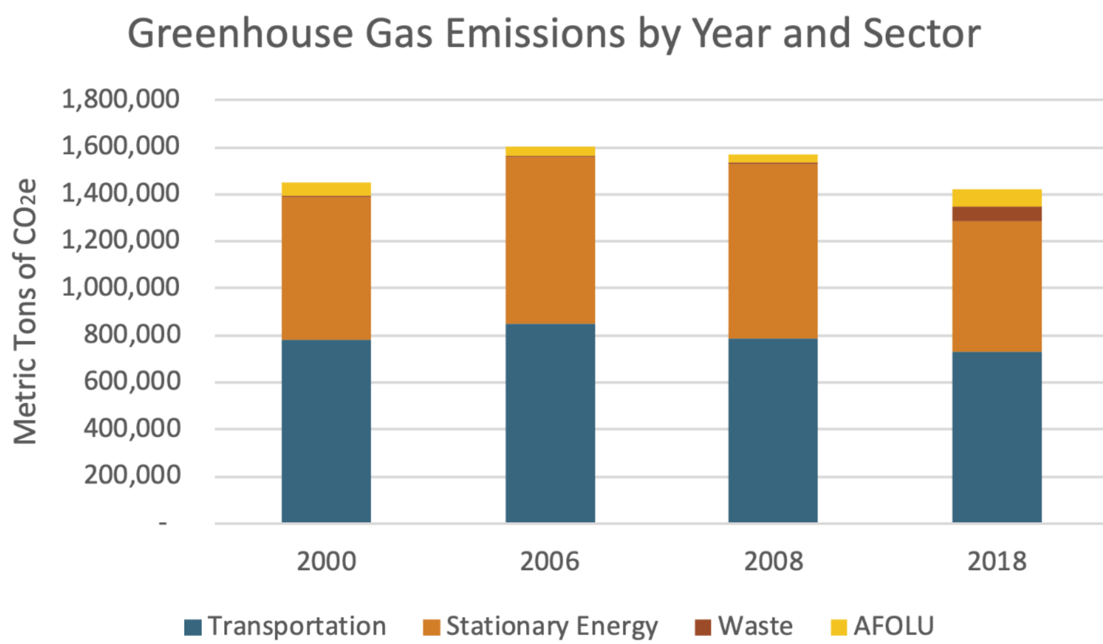
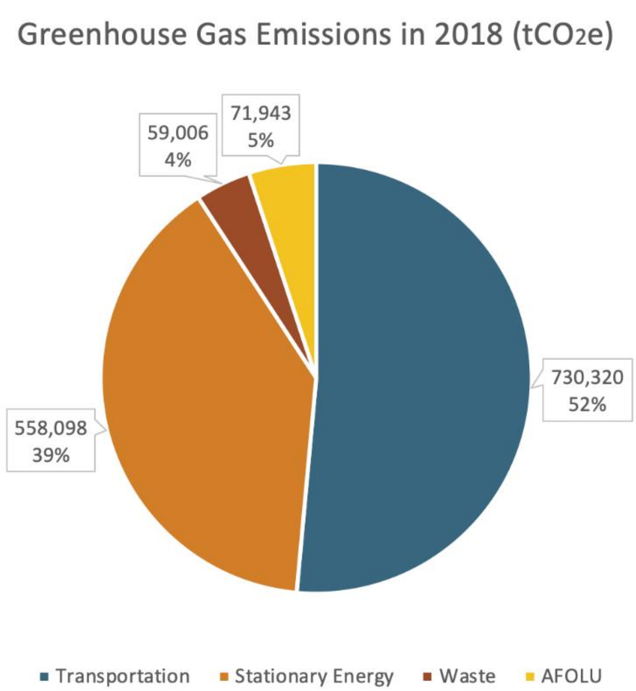


Figure 9: Community-Wide Emissions by Sector



The data in Table 4 and Figure 8 indicate that the volume of emissions for the Transportation and Stationary Energy sectors have generally decreased since 2006. Conversely, the volume of emissions from the Waste and AFOLU sectors appear to have increased—although this is likely due to differences in calculation methodologies that better capture actual emissions (discussed further in sector-specific sections below). Nonetheless, Transportation and Stationary Energy make up the vast majority—about 91%—of 2018 community-wide emissions.

Below, we present detailed methodology and results for the sectors of our inventory—Transportation, Stationary Energy, Waste, and AFOLU.

Transportation

Our inventory for the Transportation sector includes vehicle traffic on public roads within the geographic boundary of Albemarle County. Off-road transportation—such as farm, construction, and recreation vehicles not traveling on public roadways—is not counted.

Transportation emissions result primarily from fossil fuels burned within internal combustion engines of vehicles during operation. Whereas such emissions are considered direct emissions, a small amount of the total Transportation sector emissions results indirectly due to electric vehicles (EVs). EVs induce emissions from the electric grid when charging but produce no direct emissions while driving.

Transportation Methodology

We use data from the following sources, all of which is publicly available and linked in the footnotes:

- Daily Vehicle Miles Traveled (DVMT) for Albemarle County in 2018 (VDOT)[12]
- Vehicle Miles Traveled (VMT) for Virginia in 2018 by Vehicle Type (EPA)[13]
- Average Fuel Economy by Vehicle Type, gas and diesel (US EIA, US DOT)[14]
- Motor Vehicle Registrations in Virginia in 2018 (US DOT)[15]
- Electric Vehicle (EV) Registrations in Virginia in 2018 (US DOE)[16]
- Average Electric Vehicle Fuel Economy (US DOE)[17]
- Emission Factors for Greenhouse Gas Inventories, 2018 (US EPA)[18]
- Emission Factors for Greenhouse Gas Inventories, 2020, (US EPA)[19]

Understanding Vehicle Miles Traveled (VMT)

Vehicle miles traveled (VMT) is a term that describes the estimated total number of miles traversed by all vehicles on roads within a given boundary. VMT is the key measure of activity for the Transportation sector. The Virginia Department of Transportation (VDOT), which owns and operates all public roads in the County, collects data from sensors installed on roads that measure

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[12] Virginia Department of Transportation (VDOT), 2018 Traffic Data Daily Vehicle Miles Traveled, "Table 1216 - DVMT by Physical Jurisdiction, with Towns Combined into Counties, by Federal Functional Class All Roads; Town Values Reported Within County Values," https://www.virginiadot.org/info/2018_traffic_data_daily_vehicle_miles_traveled.asp.

[13] US Environmental Protection Agency, Energy Resources for State and Local Governments, Download the State Inventory and Projection Tool, "Mobile Combustion," https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool.

[14] All vehicles except motorcycles: US Energy Information Administration, API Query Browser, "Motor Vehicle Mileage, Fuel Consumption, and Fuel Economy," https://www.eia.gov/opendata/qb.php?category=711246. Motorcycles: US Department of Transportation, Bureau of Transportation Statistics, "Light Duty Vehicle, Short Wheel Base and Motorcycle Fuel Consumption and Travel," https://www.bts.gov/content/light-duty-vehicle-short-wheel-base-and-motorcycle-fuel-consumption-and-travel.

[15] US Department of Transportation, Federal Highway Administration, "State Motor-Vehicle Registrations - 2018," December 2019, accessed February 3, 2021, https://www.fhwa.dot.gov/policyinformation/statistics/2018/mv1.cfm.

[16] US Department of Energy, Alternative Fuels Data Center, "Electric Vehicle Registrations by State: U.S. light-duty electric vehicle population as of December 2018," last updated August 2020, accessed February 3, 2021, https://afdc.energy.gov/data/search?q=electric+vehicle+registrations+by+state.

[17] US Department of Energy, Alternative Fuels Data Center, "Data Sources and Assumptions for the Electricity Sources and Emissions Tool," accessed February 3, 2021, https://afdc.energy.gov/vehicles/electric_emissions_sources.html. Note that EV fuel efficiency (kWh/mile) is a weighted average of 2016 model vehicles sold in 2015. Data for 2018 was not available.

[18] US Environmental Protection Agency, "Emission Factors for Greenhouse Gas Inventories," last modified March 9, 2018, https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf. Used for Stationary Energy.

[19] US Environmental Protection Agency, "Emission Factors for Greenhouse Gas Inventories," last modified March 26, 2020, https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf. Updated 2018 values used for Transportation.

vehicle traffic loads. VDOT uses this traffic data to estimate the average Daily Vehicle Miles Traveled (DVMT) within the County's geographic boundary.[20] (We use DVMT to denote the daily count and VMT to refer to the general measure and the annual value used in our calculations.)

General Transportation Method

With the above sourced data, we derive an estimate of annual vehicle miles traveled (VMT) in Albemarle County in 2018, disaggregated by major vehicle type category.[21] We use VMT and average fuel economy by vehicle type to derive gallons of fuel consumed for each vehicle type in 2018. We then multiply gallons of fuel by the emissions factor for carbon dioxide (CO_2) and VMT by the emission factors for methane (CH_4) and nitrous oxide (N_2O) to determine the emission subtotals for each greenhouse gas. Multiplying the subtotals by their respective global warming potential puts all units in terms of equivalent carbon dioxide, which we sum to report a total as metric tons of carbon dioxide equivalent (tCO_2e).

Electric Vehicle Estimate

Because data sources only disaggregate VMT by fossil-fuel powered vehicle types, the general calculation method assumes that all vehicle traffic in Albemarle County comes from vehicles with internal combustion engines. However, electric vehicles (EVs) represent a small but exponentially growing share of the vehicle mix. In fact, in 2018 1.1% of the registered vehicles in the state were EVs.[22] Since the VMT data assumes that all vehicles are powered by fossil fuels, EVs on the road are being counted as if they were conventional gas- or diesel-powered vehicles, which artificially raises the emissions estimate. Further, because EVs are charged on the electric grid, their emissions are also counted directly in the Stationary Energy sector. This means that emissions resulting from EVs are counted in one sector and falsely counted in another sector at the same time.

In order to avoid "double counting," we construct an estimate of EV VMT and the emissions associated with charging the vehicles in our Transportation sector calculations. We then shift this emissions value from the Stationary Energy sector—within which electricity emissions are generally reflected—to the Transportation sector total, *and* we subtract from the Transportation sector the quantity of emissions these vehicles would have generated if they were powered by fossil fuels. Although the net emissions reductions due to the use of EVs—as compared to conventional vehicles—is tiny now, counting them in this way will allow us to track future progress with EV adoption.

Transportation Emissions

We calculate community-wide emissions in the Transportation sector in 2018 to be 730,320 metric tons of carbon dioxide equivalent (tCO_2e). Emissions from transportation in 2018 represented 52% of total community-wide emissions.

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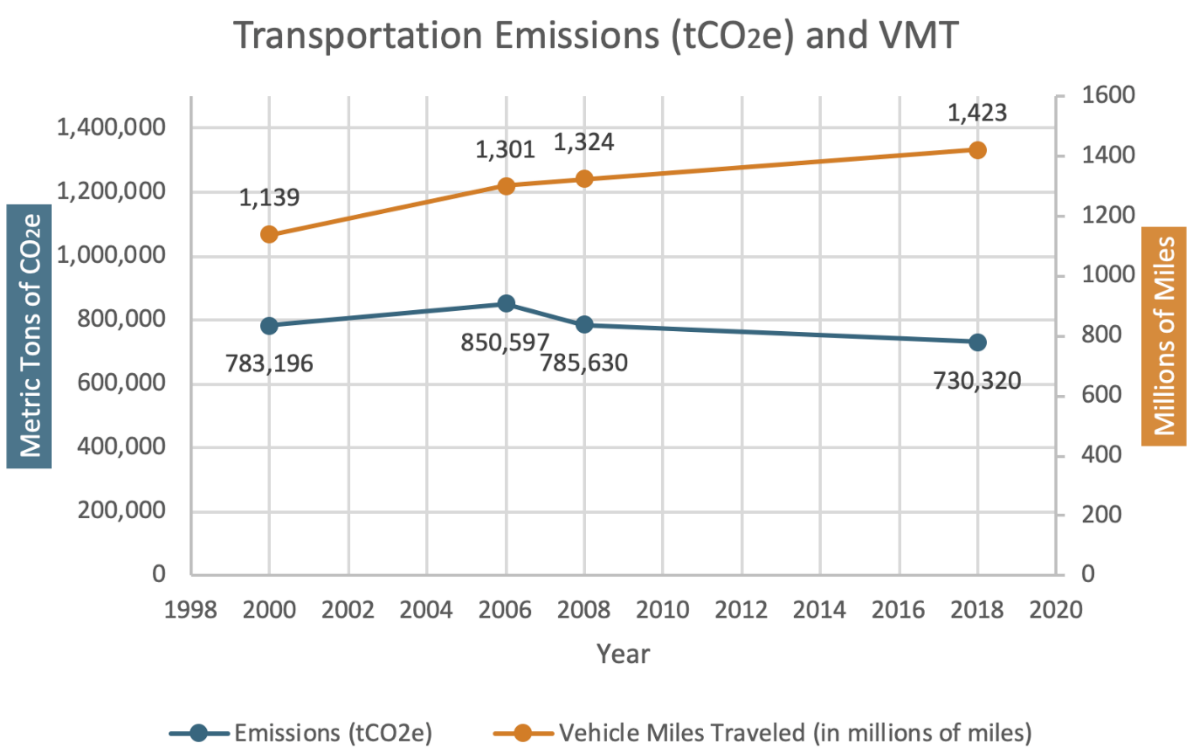
[20] Virginia Department of Transportation, "Traffic Data," accessed February 10, 2021, https://www.virginiadot.org/info/ct-TrafficCounts.asp. Additional information on VDOT's methods for counting DVMT can be found at https://www.virginiadot.org/info/2018_traffic_data_vmt_reporting_methodology.asp.
[21] There are seven major vehicles types listed in data for vehicle miles traveled (VMT): light-duty gasoline vehicle, light-duty diesel vehicle, light-duty gasoline truck, light-duty diesel truck, heavy-duty gasoline truck, heavy-duty diesel truck, and motorcycle.
[22] For an overview of global electric vehicle growth over the past decade, see: IEA (2020), *Global EV Outlook 2020*, IEA, Paris, https://www.iea.org/reports/global-ev-outlook-2020.

Below, we show the change in transportation emissions over time for each year that Albemarle County has conducted a greenhouse gas emission inventory. Figure 10 depicts transportation emissions and vehicle miles traveled (VMT) in the County for each inventory year. (VMT numbers are rounded to the nearest million miles.)

Figure 10: Transportation Emissions (tCO_2e) and Vehicle Miles Traveled (VMT)



The graph shows that emissions from the Transportation sector have been decreasing since 2006, even as transportation activity has increased steadily over time. From 2008 to 2018, transportation emissions decreased by 7%, even as VMT increased by 7%.

There are two likely explanations for this counterintuitive trend: First, fuel efficiency has improved by about 4.5% over the same time period.[23] Even as vehicles have traveled more miles, they have burned fewer gallons of fuel for each mile traveled. Second, emission factors for methane (CH_4) and nitrous oxide (N_2O) have decreased over time, meaning vehicles have produced less of these powerful greenhouse gases as byproducts of fuel combustion.[24] This trend has a similar effect on overall greenhouse gas emissions as the trend in fuel efficiency, shown above.

A minor contributing factor to increasing vehicle efficiency is the use of electric vehicles (EVs). In 2018, local EV use resulted in emissions of 169 tCO_2e due to EVs being charged by the electric

[23] US Energy Information Administration, API Query Browser, "Motor Vehicle Mileage, Fuel Consumption, and Fuel Economy," https://www.eia.gov/opendata/qb.php?category=711246.
[24] US Environmental Protection Agency, "Emission Factors for Greenhouse Gas Inventories," last modified March 26, 2020, https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf. Updated 2018 values used for Transportation.

grid but also resulted in the avoidance of 564 tCO_2e in emissions by not directly burning petroleum—a net reduction of 395 tCO_2e of emissions.

Stationary Energy

The community Stationary Energy sector consists of the energy consumed by buildings and other stationary structures in Albemarle County, such as streetlights. These emissions result from three main types of energy consumption: (1) electricity use by buildings and other stationary objects, (2) natural gas for heating and cooking in buildings served by Charlottesville Gas, and (3) other fuel types—such as fuel oils, propane, and firewood—used for heating and cooking in buildings not served by a utility.

The local activity data includes metered electricity and natural gas provided by utilities, as well as estimates for other combustible fuels consumed by buildings in the community. These emissions are generally reported by building subcategory: Residential, Commercial, Industrial, and Government/Other.

Stationary Energy Methodology

We use data from the following sources:

- Electric utility reports for 2018 (Dominion Energy, Appalachian Power, Roanoke Electric Cooperative, Central Virginia Electric Cooperative)
- Albemarle County Community Natural Gas Consumption, 2018 (Charlottesville Gas)
- Other house heating fuels in 2018 (US Census Bureau)[25]
- Emission Factors for Greenhouse Gas Inventories, 2018 (US EPA)[26]
- Emission Factors for Greenhouse Gas Inventories, 2020, (US EPA)[27]
- Emissions & Generation Resource Integrated Database (eGRID), (US EPA)[28]

Electricity

Four electric utility providers operate within Albemarle County: Dominion Energy, Appalachian Power, Central Virginia Electric Cooperative, and Rappahannock Electric Cooperative. These utilities provided date reflecting electricity usage (*activity*) in annual kilowatt hours (kWh) for four building categories: Residential, Commercial, Industrial, and Government/Other.

To calculate emissions from electricity generation, we multiply total electricity usage by an aggregate emission factor already expressed in terms of carbon dioxide equivalent units, provided by the EPA for Virginia's electric grid. The product is the total metric tons of greenhouse gas emissions (tCO_2e) from electricity used within the County.

[25] US Census Bureau, "Physical Housing Characteristics for Occupied Housing Units," 2018: ACS 1-Year Estimates Subject Tables, American Community Survey, accessed February 5, 2021, https://data.census.gov/cedsci/table?q=S25&g=0500000US51003&d=ACS%201-Year%20Estimates%20Subject%20Tables&tid=ACSST1Y2018.S2504&hidePreview=true.

[26] US Environmental Protection Agency, "Emission Factors for Greenhouse Gas Inventories," last modified March 9, 2018, https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf. Used for Stationary Energy.

[27] US Environmental Protection Agency, "Emission Factors for Greenhouse Gas Inventories," last modified March 26, 2020, https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf. Updated 2018 values used for Transportation.

[28] US EPA, Emissions & Generation Resource Integrated Database (eGRID), Data Explorer, last modified September 21, 2020, accessed February 3, 2021, https://www.epa.gov/egrid/data-explorer. Used for electricity generation emissions (Scope 2).

Natural Gas

Charlottesville Gas—the local natural gas utility—serves portions of urban Albemarle County. Charlottesville Gas provides usage data in annual cubic feet of natural gas consumed, using the same building type categories as electric utilities—Residential, Commercial, Industrial, and Government/Other.

To calculate emissions from natural gas, we multiply the total natural gas usage in Albemarle County by emission factors for each greenhouse gas to calculate respective emissions; we then convert emissions into carbon dioxide equivalent units and report the sum.

Other Fuels (Fuel Oils, Propane, Wood)

Some buildings not served by utility natural gas—primarily homes in the Rural Area—use other energy sources for heating, such as fuel oil, propane, and wood. The US Census Bureau provides data on the number of housing units in Albemarle County using other types of fuel. However, because these fuels are not provided by a metered utility, there is no precise data on the *amount of fuel* used each year. We estimate usage for these fuels by calculating an average amount of heat energy generated per year—in British thermal units (BTUs)—for a typical household based on residential natural gas usage provided by the utility Charlottesville Gas. We estimate the quantity of these other fuels consumed by households assuming the heating needs are the same as those using natural gas. Multiplying the quantities of other fuels burned by each fuel's respective emission factors provides an estimate of greenhouse gas emissions, which we report in terms of tCO_2e.

Stationary Energy Emissions

We calculate community-wide emissions in the Stationary Energy sector in 2018 to be 558,098 metric tons of carbon dioxide equivalent (tCO_2e). Emissions from this sector in 2018 represented 39% of total community-wide emissions.

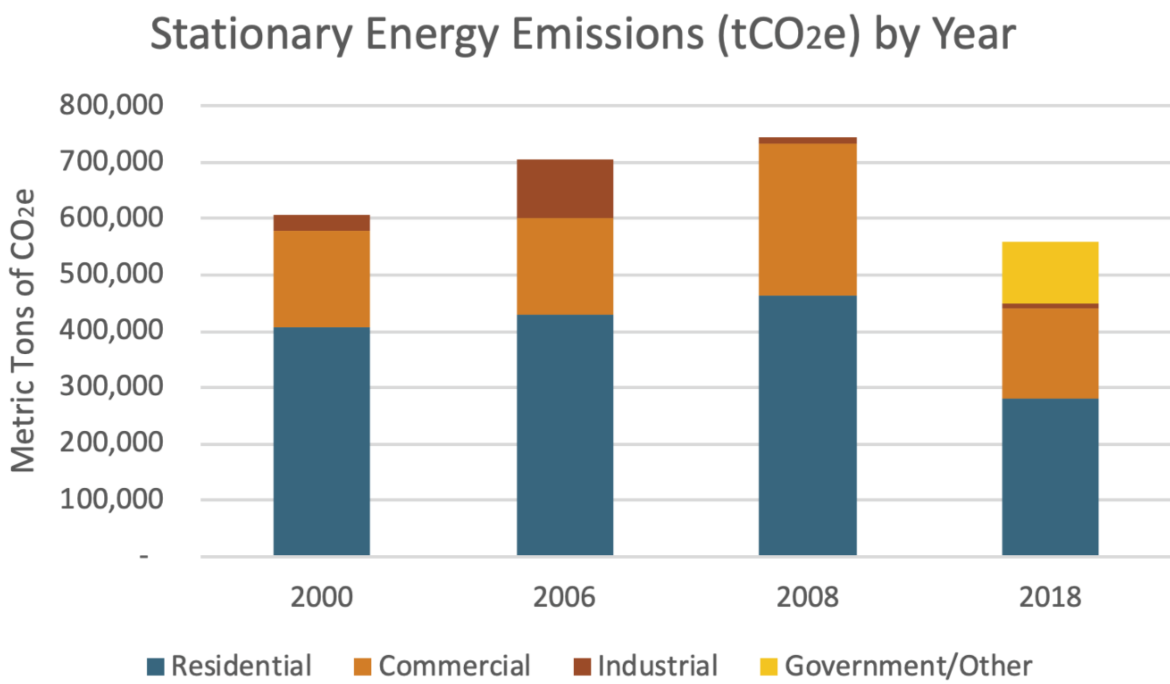
Below, we show the change in Stationary Energy emissions over time for each year that Albemarle County has conducted a greenhouse gas emission inventory. Table 5 reports emissions and activity in the County for each inventory year, and Figure 11 depicts these numbers visually.

Table 5: Stationary Energy Emissions (tCO_2e)

Emissions by Year (tCO_2e)	2000	2006	2008	2018
Residential	405,974	428,308	461,997	279,481
Commercial	173,148	171,905	270,181	161,397
Industrial	28,067	105,235	13,040	8,376
Government/Other*	Not reported	Not reported	90,187*	109,013
EV Subtraction**	N/A	N/A	N/A	-169
Total Stationary Emissions Reported	**607,189**	**705,448**	**745,218**	**558,098**

*We sourced the Government/Other quantity for 2008 from utility companies. However, this number was not reported or counted in 2008 totals in the County's 2009 report. We have reported the number here for transparency, but we have omitted it from the sum for 2008 to match that report. We include this category in our total for 2018.
**Electric Vehicle (EV) emissions from charging are subtracted from the Stationary Energy sector and calculated within the Transportation sector to reflect the source of induced emissions.

Figure 11: Stationary Energy Emissions (tCO_2e) by Inventory Year

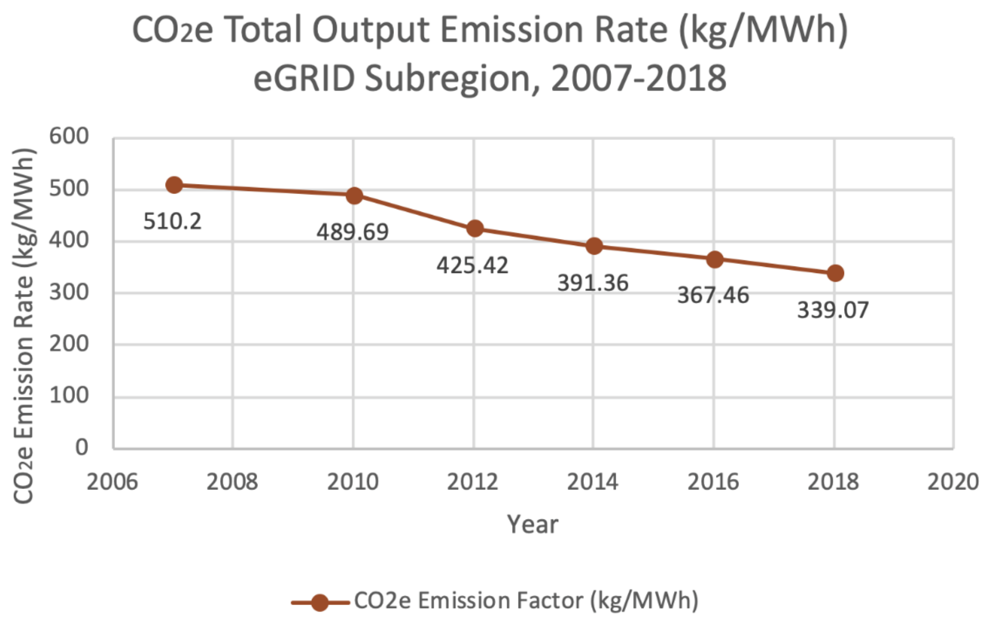


Above, Table 5 and Figure 11 show a large drop in emissions from building energy use from 2008 to 2018. At the same time, overall building energy use has increased across the community—likely due to development and population growth.

What accounts for the counterintuitive decrease in greenhouse gas emissions even as energy use has increased? Installation of rooftop solar panels by residents and businesses may explain some of the observed decrease in emissions. The major factor is likely that electricity generation in Virginia has become "cleaner" over time. In 2007, the burning of coal accounted for nearly 45% of the electricity generated for use across the state of Virginia. By 2018, coal's share of electricity generation had fallen to less than 10%. During this same period, natural gas rose from less than 14% to 52%.[29] Although natural gas is still a fossil fuel that produces carbon dioxide when burned—and is not a form of renewable energy—it produces less carbon dioxide than coal per unit of electricity generated. Small, but much less significant, increases occurred for several renewable sources. This shift in the composition of sources of electricity generation in Virginia is reflected in the emission factor provided by the EPA.[30] That emission factor has decreased by 34% since 2007 (numbers for 2008 are not available). Figure 12 depicts the decrease over time in the emission factor for electricity generation.

[29] "Year 2007 State Resource Mix," *eGRID2010 Version 1.1: Year 2007 Summary Tables*, 11; "State Resource Mix (eGRID2018)," *eGRID Summary Tables 2018*, 5; accessible at https://www.epa.gov/egrid/download-data.
[30] US EPA, Emissions & Generation Resource Integrated Database (eGRID), Data Explorer, last modified September 21, 2020, accessed February 3, 2021, https://www.epa.gov/egrid/data-explorer.

Figure 12: Decreasing Emission Factor for Electricity Generation



There is an important caveat: Although natural gas is generally considered a "cleaner" source of electricity generation than coal because the former produces fewer greenhouse gas emissions when burned, natural gas (consisting of mostly methane, CH_4) is itself a potent greenhouse gas, having nearly 30 times the global warming potential as carbon dioxide (CO_2). Scholars and watchdog groups have raised important questions about the extent to which methane leaks into the atmosphere during the extraction and transport of natural gas from the well to the electric utility.[31] The precise amount of leakage and its impact on global warming is not fully known; it is clear, however, that a consequential amount of methane leaks from wells, lessening the apparent climate benefit of shifting from burning coal to burning natural gas. Therefore, it is very likely that the protocols we follow for this inventory lead to underestimating emissions for the Stationary Energy sector. This uncertainty speaks to the importance of transitioning to fully renewable, clean energy (e.g., solar and wind), called for in Albemarle County's Climate Action Plan.

Waste

Greenhouse gas emissions from waste principally result from the degradation of organic waste (e.g., food scraps, paper products, garden waste, lumber) into methane (CH_4). When organic waste ends up in a landfill (instead of being composted), bacteria consume the organic matter in an anaerobic (no oxygen) environment, producing methane as a byproduct. While technologically advanced landfills can capture some of this methane, much of it is released into the atmosphere where it contributes to global warming at a rate of nearly 30 times that of carbon dioxide (CO_2).

[31] Benjamin Storrow, "Methane Leaks Erase Some of the Climate Benefits of Natural Gas," Scientific American, May 5, 2020, https://www.scientificamerican.com/article/methane-leaks-erase-some-of-the-climate-benefits-of-natural-gas/; Jeff Tollefson, "Methane leaks erode green credentials of natural gas," Nature 493, no. 12 (2013), https://doi.org/10.1038/493012a.

Waste Methodology

Our inventory for the Waste sector accounts for greenhouse gases resulting from the disposal of municipal solid waste (MSW) produced by residents of Albemarle County. We use local data on per capita solid waste from recycling rate reports produced by Thomas Jefferson Planning District Commission (TJPDC).[32]

In broad terms, calculating emissions from solid waste involves estimating the portion of municipal solid waste that degrades into methane. Many variables affect this estimate, including (but not limited to): waste composition, whether a landfill is managed or unmanaged, the fraction of degradable organic carbon that actually degrades (some doesn't), and the fraction of methane recovered at the landfill (by flaring or recovery for energy use).

We calculate solid waste emissions using the "methane commitment" method from the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), which involves three equations that produce estimates of key factors and, ultimately, an estimate of methane emissions.[33] The actual numbers for variables in these equations come from three sources: (1) our local estimate of municipal solid waste based on TJPDC's reports, (2) assumed values based on guidance from the GPC and ICLEI-Local Governments for Sustainability, and (3) values derived from the equations themselves.

The first equation allows us to calculate the amount of *degradable organic carbon* within a unit amount of solid waste based on the percentage of waste constituents containing organic matter (e.g., food scraps, garden waste, paper products, wood). Degradable organic carbon interacts with microbes in a landfill to produce methane, in contrast to other constituents—like plastic and metal—that are inert. We use ICLEI's estimates of waste composition for US communities to estimate percentages of food scraps, garden waste, paper products, and wood in the waste stream.

With the second equation, we estimate the *methane generation potential* of solid waste; this number reflects the *emission factor*. The equation accounts for the type of landfill (assumed to be managed), the amount of degradable organic carbon in the waste, the fraction of this degradable organic carbon that actually degrades, and the fraction of methane in landfill gas (which contains other compounds, including carbon dioxide).

The third equation resembles the basic calculation of greenhouse gas emissions: *(activity) x (emission factor) = (GHG emissions)*. In this case, it is the product of the quantity of local municipal solid waste (the *activity*) and the methane generation potential derived from the second equation (the *emission factor*), which yields an estimate of methane emissions.[34] Using methane's global warming potential, we report these in terms of tCO_2e.

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[32] Thomas Jefferson Planning District Commission, "2016 Recycling Rate fact sheet," Solid Waste Planning: Recycling Rate Reports, accessed March 23, 2021, https://tjpdc.org/our-work/solid-waste/. We use the per capita estimate from 2016, as TJPDC has not produced a comparable report since that year.
[33] *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*, 90-94.
[34] This third equation includes two additional factors. One is an assumed value based on GPC guidance. The other is an estimate of the fraction of methane recovered at the landfill and either flared or used for energy generation (and thus, not emitted into the atmosphere). In the absence of data specific to the landfills used by Albemarle County, we estimate this fraction based on a range provided by the US Environmental Protection Agency (EPA). The EPA estimates that landfills in the US recover between 60 and 90 percent of methane produced before it escapes into the atmosphere (see https://www.epa.gov/lmop/benefits-landfill-gas-energy-projects). We use 75% in our calculation. As we gain access to more precise data, we will refine and update our calculations.

Waste Emissions

We calculate community-wide emissions from municipal solid waste in 2018 to be 59,006 metric tons of carbon dioxide equivalent (tCO_2e). Emissions from solid waste in 2018 represented 4% of total community-wide emissions.

Below, we show the change in waste emissions over time for each year that Albemarle County has conducted a greenhouse gas emission inventory. Figure 13 depicts waste and its associated emissions in the County for each inventory year.

Figure 13: Solid Waste Emissions (tCO_2e) by Inventory Year

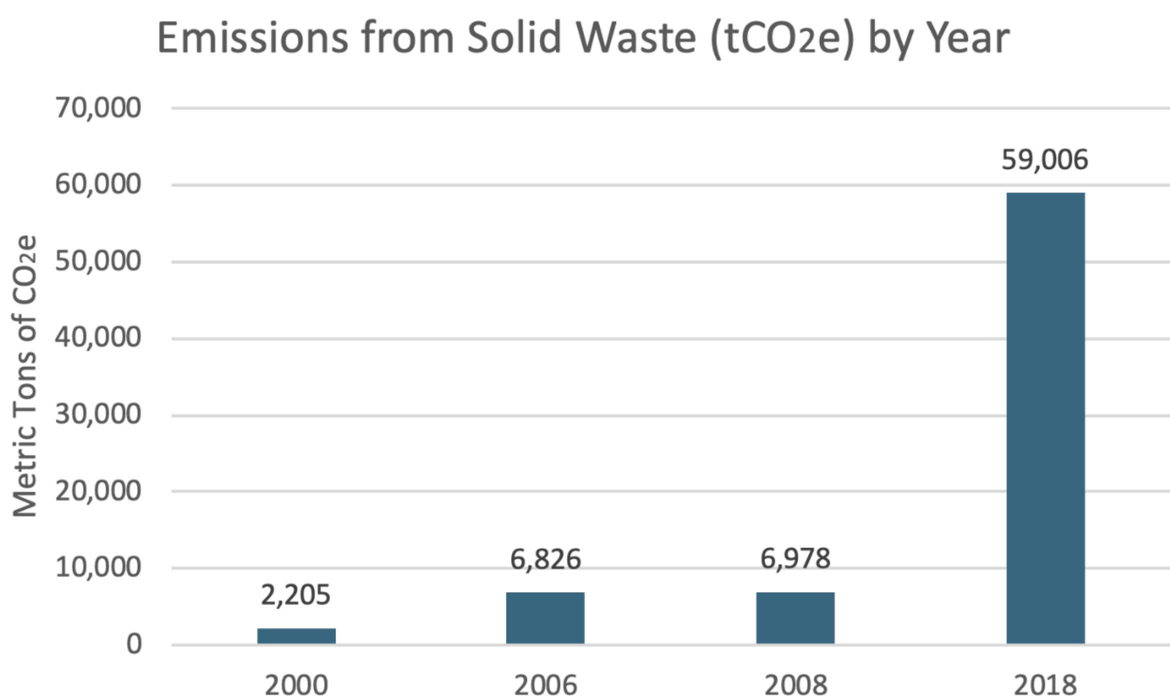


Figure 13 shows a significant increase in solid waste production and in emissions from organic waste between 2008 and 2018. Readers may notice that the increase in emissions from solid waste is disproportionately large compared to the increase in solid waste itself. Several factors may have contributed to the reported increases in waste and waste-generated emissions:

- Past undercounting of the activity – The process used by TJPDC to calculate community waste tonnage in 2018 differs from the process used in 2000, 2006, and 2008. The 2018 process appears to be more accurate, so tonnage in earlier years was likely considerably undercounted.
- Methodological inconsistency – The method and assumptions we used to calculate greenhouse gas emissions per unit of solid waste appears to differ from the method and assumptions used in previous years. Unfortunately, we do not have access to the method used by staff in 2000, 2006, and 2008, so an evaluation of the differences is not possible.
- Sensitivity to unknown variables – The methodology that we used for 2018 allows for a considerable range of *possible* emissions from solid waste due to assumptions made about

the value of key variables in the equations used to calculate waste emissions. For instance, the quantity of emissions per unit of municipal solid waste is highly sensitive to the fraction of methane that is recovered at the landfill for flaring or energy use. Some sources suggest that anywhere from 10% to 90% of methane may be recovered—resulting in a range for community-wide emissions in 2018 of 14,752 tCO_2e to 132,764 tCO_2e. In the US, the EPA estimates that landfills with landfill gas energy projects may capture between 60% and 90% of methane. We don't have actual data on methane recovery at the landfills that receive Albemarle County's solid waste, so we used 60% as a conservative estimate, which yields 59,006 tCO_2e. We acknowledge that there is significant uncertainty in the actual value, but we believe our method represents an increase in accuracy over previous years' estimates.

Agriculture, Forestry, and Other Land Uses (AFOLU): Livestock Emissions

Greenhouse gas emissions in the category of agriculture, forestry, and other land uses (AFOLU) result from many sources. Examples in agriculture include soil degradation from unsustainable growing practices (e.g., tillage),[35] enteric fermentation and manure from livestock, and machinery powered by fossil fuels. Emissions from forestry includes soil degradation from monoculture farms[36] and clearcutting old-growth forests, as well as from machinery used in forestry operations. Examples of other land uses that generate greenhouse gas emissions include clearing land or draining wetlands for construction.

Our 2018 inventory *only accounts for emissions from livestock* (cattle, horses, sheep, goats, swine, and chicken). This does not mean that livestock are the only source of emissions in this sector in Albemarle County; rather, the limitation represents a challenge in measurement. New methods have been developed in recent years to account more accurately for emissions (and sequestration) associated with forests, farmland, and other land use types. In Appendix A, we report data from a pilot method to account for emissions and sequestration based on change in land cover. As it becomes clearer how additional methods fit within the overall profile of Albemarle County's emissions inventory, we will assess how to incorporate the information into our accounting in this sector.

AFOLU Methodology

Emissions from livestock include methane (CH_4) and nitrous oxide (N_2O) produced by *enteric fermentation* and *manure management*. We use data on livestock populations from the USDA National Agriculture Statistics Service (NASS) Census of Agriculture, Virginia (2017).[37]

As with previous emission sectors, the quantity of greenhouse gas emissions is the product of an emission factor and an activity. We first multiply the livestock population by daily rates of enteric fermentation and manure per animal to yield the *activity*. We then multiply that product by *emission factors* for methane and nitrous oxide to calculate emissions. The actual equations, which

[35] "Farming New Land Can Release Lots of CO2 into the Atmosphere," Climate Central, January 28, 2009, https://www.climatecentral.org/library/climopedia/farming_new_land_can_release_lots_of_co2_into_the_atmosphere.
[36] Corsa Lok Ching Liu, Oleksandra Kuchma, and Konstantin V. Krutovsky, "Mixed-Species Versus Monocultures in Plantation Forestry: Development, Benefits, Ecosystem Services and Perspectives for the Future," *Global Ecology and Conservation* 15 (2018), https://doi.org/10.1016/j.gecco.2018.e00419.
[37] Census of Agriculture, 2017 Census Volume 1, Chapter 2: County Level Data, Virginia, accessed March 26, 2021, https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/Virginia/.

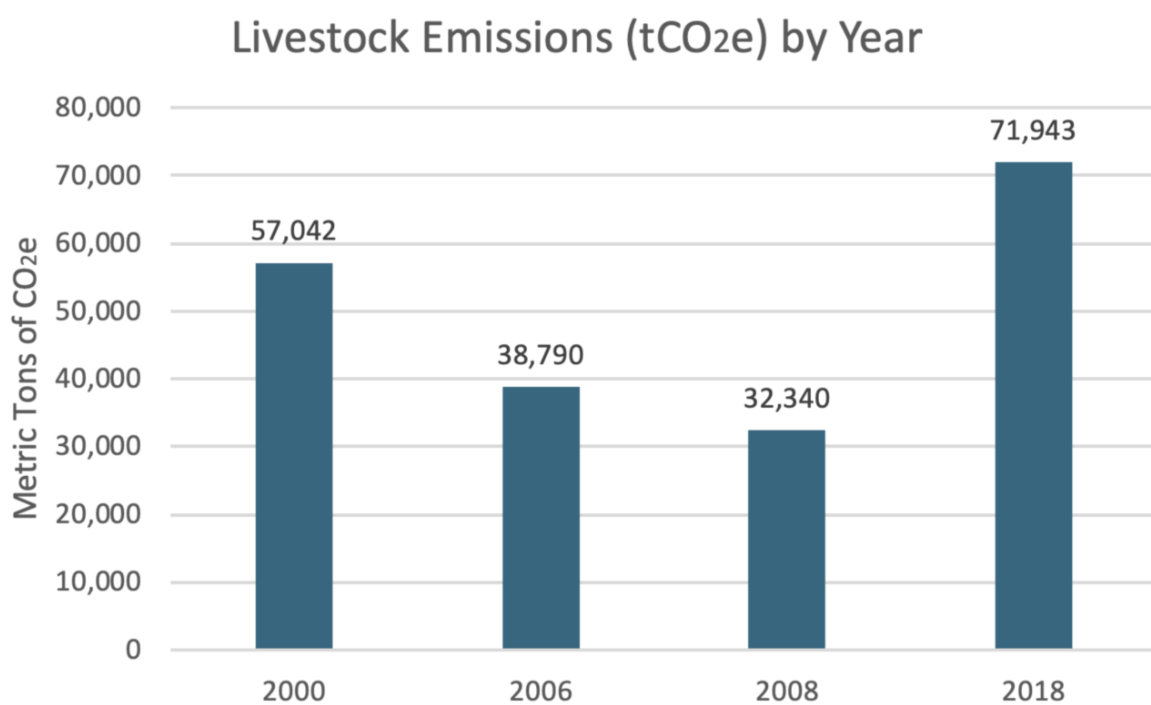
are more complex than what is warranted for this summary, are derived from methodology detailed in "Appendix G: Agricultural Livestock Emission Activities and Sources" of the *U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions*.[38]

This methodology includes calculations for methane emissions from enteric fermentation and from manure, as well as for nitrous oxide emissions from manure.[39]

AFOLU Emissions

We calculate community-wide emissions from livestock in 2018 at 71,943 metric tons of carbon dioxide equivalent (tCO_2e). Emissions from livestock in 2018 represented 5% of community-wide emissions across all sectors. Figure 14 depicts livestock emissions across the years that Albemarle County has conducted emission inventories.

Figure 14: Emissions from Livestock (tCO_2e) by Inventory Year



It is worth noting that in addition to contributing to methane (CH_4) and nitrous oxide (N_2O) emissions through enteric fermentation and manure, livestock can bring ecological benefits—including supporting carbon sequestration in soil—through certain types of land management and

[38] ICLEI – Local Governments for Sustainability USA, "Appendix G: Agricultural Livestock Emission Activities and Sources," in *U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions*, Version 1.1 (2013).
[39] Although the state of Virginia provides countywide census information for total livestock numbers, disaggregated data for types of cattle, including dairy and beef, tend to be incomplete or withheld. For example, while we know the total number of cattle in Albemarle County and the number of farms engaged in beef and dairy operations, we do not know the numbers of cattle in each type of operation, much less the numbers of cattle subtypes within these categories (e.g., cows, heifers, steers). We therefore make rough estimates of weighted averages of cattle for total animal mass, volatile solid rates, and Kjeldahl nitrogen rates, which the *U.S. Community Protocol* provides for each subtype of cattle.

grazing techniques.[40] In other words, unlike other sectors for which reducing the *activity* is generally beneficial (e.g., driving less, conserving energy, reducing waste), reducing emissions from agriculture is less about reducing the activity and more about changing *how* we engage in that activity. Albemarle County's Climate Action Plan outlines a variety of approaches to ecological land management and sustainable agricultural practices.[41]

Albemarle County Local Government and Public Schools Inventory Subset

As mentioned previously, we conduct an inventory of greenhouse gas emissions for local government as a subset of the community-wide inventory to inform policy and operations. Local government emissions are already counted in the above data sources and calculations. We counted in this subset emissions that result from the operation of County-owned buildings, streetlights, and vehicles, as well as the commutes of County employees. These emissions can also be categorized within the Transportation and Stationary Energy sectors.

Local Government and Public Schools Methodology

The following data sources allow us to isolate the contribution of local government within community-wide emissions:

- Albemarle County Energy Management System database
- Albemarle County Public Schools Transportation Department and Albemarle County Fire Rescue fuel purchase records
- Albemarle County Employee Home and Work Addresses (confidential)

Buildings, Vehicle Fleet, and Streetlights

For County buildings, vehicle fleet, and streetlights for which the County is charged, we calculate greenhouse gas emissions by applying the appropriate emission factors to energy and fuel consumption data tracked by the County.

Employee Commute

We use ArcGIS Pro, a geographic information systems (GIS) software, to conduct a network analysis based on employee permanent addresses and places of work. After assigning each employee an origin and destination (address and place of work), we calculate commute distance in miles for every employee in the database. We then multiply the round trip by number of days per year that every employee commutes to derive total employee vehicle miles traveled (VMT) in 2018. We multiply this value by an emission factor, already in terms of tCO_2e, a sum of emissions from carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

To avoid counting outliers—employees with permanent addresses very far from their place of work who likely don't actually live at this address or work remotely—we only considered commutes less than or equal to 100 miles—one-way—in the final calculation, which accounts for 85% of potential employee commutes. For the remaining 15% of employee commutes, we use the

[40] For example, "managed grazing" can rebuild healthy grasslands and soils, allowing these ecosystems to sequester carbon. See Project Drawdown on "Managed Grazing" (https://www.drawdown.org/solutions/managed-grazing) and "Silvopasture" (https://www.drawdown.org/solutions/silvopasture).
[41] See https://www.albemarle.org/government/facilities-environmental-services/environmental-stewardship/climate-protection.

mean commute distance for all employees to approximate this group. Because the 100-mile cutoff is somewhat arbitrary, a future employee survey may be used to acquire a more accurate set of commute distances, instead of using the permanent address on file for each employee.

Local Government and Public Schools Emissions

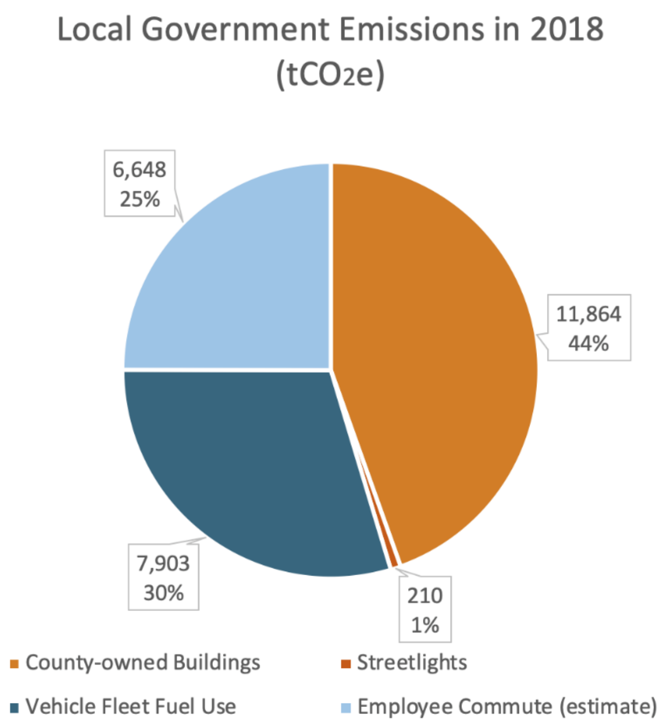
We estimate emissions from the operations of local government and public schools to be 26,625 tCO_2e—roughly 2% of the community total.

Transportation emissions from employee commutes and the use of County-owned vehicles totaled 14,551 tCO_2e—about 55% of local government emissions but only 2% of the community-wide Transportation sector). Emissions from County-operated buildings and streetlights were 12,074 tCO_2e—about 45% of local government emissions but only 2% of the community-wide Stationary Energy sector).[42]

The County does not track the amount of solid waste generated by local government operations, so we do not report the emissions for solid waste for local government and public schools.

In Figure 15, we report the composition of local government emissions *by emission sector* (blue and orange coloring) and *by operational area* (individual wedges).

Figure 15: Local Government and Public Schools Emissions by Source (tCO_2e)



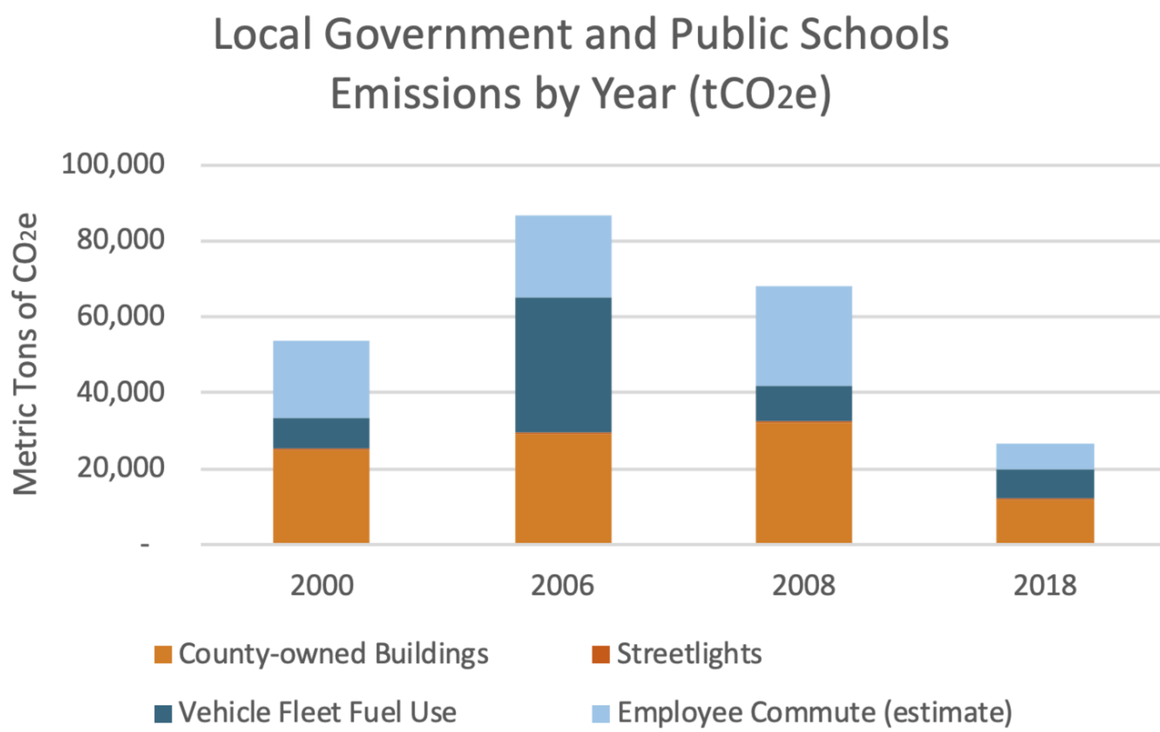
In Table 6 and Figure 16, we report the total emissions for local government and public schools across the four years that Albemarle County has conducted greenhouse gas emission inventories.

Table 6: Local Government and Public Schools Emissions by Year (tCO_2e)

Year	2000	2006	2008	2018
County-owned Buildings (tCO_2e)	25,013	29,019	32,220	11,864
Streetlights (tCO_2e)	267	473	422	210
Vehicle Fleet (tCO_2e)	8,027	35,696	9,247	7,903
Employee Commute (tCO_2e)	20,224	21,576	26,120	6,648
Total (tCO_2e)	**53,531**	**86,764**	**68,009**	**26,625**

[42] Note that the Government/Other category in community-wide emissions is larger than the local government subset because the former includes buildings owned and operated by government entities other than Albemarle County (e.g., University of Virginia, federal, and state facilities).

Figure 16: Local Government and Public Schools Emissions by Year (tCO₂e)



Readers may notice the especially large drop in emissions from 2008 to 2018. We were unable to confirm the methodology used in 2008, so we cannot rule out the possibility of methodological differences. Aside from this possible inconsistency, two other factors may explain part of the significant drop in emissions:

- **Changes to Electricity Generation:** As discussed in the Stationary Energy section, electricity generation appears to have become cleaner in the past decade. This may explain a portion of the drop in emissions from County-operated buildings between 2008 and 2018.
- **Changes to County Building Portfolio:** In previous years, the Emergency Communications Center, the Regional Jail, and the Blue Ridge Detention Center—all large energy users—were included in the County's portfolio of buildings. Although these buildings are located in the County's geographic boundary and are counted within the Government/Other category for community-wide emissions, they do not fall within the operational control of the County's local government. In 2018, therefore, we removed these buildings from the portfolio of buildings in the local government and public schools subset. (We also included some small- and medium-size energy users not included in previous inventories, such as libraries and Fire & Rescue stations.)

Conclusions and Future Directions

Conclusions

From 2008 to 2018, community-wide emissions in Albemarle County decreased, largely due to factors outside of our direct influence, such as improvements to vehicle fuel efficiency and changes in the sources of electricity generated for the regional electric grid. Despite this decrease in emissions, the community will need to increase the pace of reducing greenhouse gas emissions for us to achieve the 2030 and 2050 reduction targets set by the Board of Supervisors in October 2019.

With the adoption of the County's first Climate Action Plan (CAP) by the Board of Supervisors in 2020, the County now has a program in place to advance a broad set of actions designed to promote community-wide emission reductions in the coming years and decades. The purpose of this CAP, in other words, is to increase the pace of reducing emissions. If we are successful in implementing the CAP, we should expect to see an increase in the pace of greenhouse gas emission reductions in future inventories, following the steeper downward slope of the dashed green line in Figure 6.

Future Directions

The County's Climate Action Plan commits us to conduct greenhouse gas emission inventories every two years, starting with 2018. With this pace of inventories, we will be better able to monitor progress and adjust our climate action work accordingly to meet our targets.

The future will also provide opportunities for us to incorporate additional emission calculations, as data and methods become available. One likely example is accounting for the sequestration of carbon dioxide by forests and other natural landscapes based on policies and programs in our CAP—as well as emissions due to loss of such landscapes. In Appendix A, we describe a new tool we've already utilized that is focused on the greenhouse gas effect of forests and trees. This will allow us to assess the progress of actions that we take to protect and enhance the local natural environment. In addition, we will also explore data now being generated by the Virginia state government related to the effect of agricultural practices adopted by growers in Albemarle County. This data will allow us to create a more robust inventory of agriculture, which is currently limited to livestock emissions.

Glossary of Terms

activity – any use of energy resulting in emissions of greenhouse gases that is included in this inventory

emission factor – the quantity of various greenhouse gasses emitted per unit of activity

emission sectors – major categories of activities resulting in greenhouse gas emissions

emission reduction targets – long-term, goals set by the Board of Supervisors for the reduction of community-wide greenhouse gas emissions

Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) – a set of standards to prepare greenhouse gas emission inventories, developed specifically for local governments

global warming potential – a number comparing the heat-trapping potential of a gas compared to that of carbon dioxide

greenhouse gas (GHG) – a gas that contribute to the greenhouse effect by absorbing infrared radiation (e.g., carbon dioxide, methane, and nitrous oxide)

ICLEI – a global network of local governments dedicated to sustainability, resilience, and climate action

Intergovernmental Panel on Climate Change (IPCC) – A United Nations body that assesses the science related to climate change

metric tons of carbon dioxide equivalent (tCO2e) – the standard unit for representing an aggregated amount of various greenhouse gas emissions, expressed as an amount of carbon dioxide only

per capita emissions – the amount of greenhouse gases emitted per person, on average

sequestration – the capture and long-term storage of greenhouse gases, for instance by vegetation and soils

vehicle miles traveled – term used in transportation planning as a measure of the amount of all travel for all vehicles in a given area over a given time period.

zero net emissions - the amount of greenhouse gases emitted is balanced by an equivalent amount of greenhouse gases sequestered

Appendix A: Forests' Effect on Greenhouse Gases

For the first time, Albemarle County has utilized a new tool from ICLEI to estimate the effect of forests and trees throughout the County on greenhouse gases—particularly carbon dioxide. This tool—called Land Emissions and Removals Navigator (LEARN)—accounts for the *sequestration* of carbon due to forest growth and the *release* of carbon due to forest loss occurring over time.

Carbon sequestration refers to the natural capture and storage of carbon dioxide by plants. Net sequestration results from the growth of undisturbed forest, the transition from non-forested areas to forest, the growth of trees outside of forests, and, to a certain extent, from durable wood products harvested sustainably (which lock up carbon in long-lived goods). Carbon emissions result from forest disturbances, the transition of forest to settlement (i.e., development), to grassland, or to other non-forested lands, and loss of trees outside of forests.

To conduct this analysis, we obtained the National Land Cover Database (NLCD)[43] for 2008 and 2016, the two years in the dataset closest to the baseline year (2008) for our emission reduction targets and the report year (2018). Analyzing the amount of each land cover type in the County that existed in years 2008 and 2016, LEARN computes the amount of undisturbed forest and any conversions from one land cover type to another between the two points in time. From these resulting data and using sequestration and emission factors, the tool calculates the total amount of carbon dioxide equivalent (CO_2e) either sequestered by forest growth or released by forest loss. The tool reports sequestration and emissions as an *annual average*.

The estimated annual amounts of sequestration and emissions for each category are summarized in the following table:

Land Cover / Conversion / Use	**average annual effect (2008 - 2016) (tCO_2e/year)**	
	Sequestration	**Emissions**
Undisturbed Forest	-894,981	0
Forest Disturbances	0	64,697
Non-Forest to Forest	-24,607	0
Forest to Settlement	0	5,785
Forest to Grassland	0	89,898
Forest to other non-forest lands	0	25
Trees outside of forests	-141,127	8,316
Harvested Wood Products	-53,738	0
Total	**-1,114,453**	**168,721**
Net GHG Balance	**-945,732**	

Since the LEARN tool is new and this is the first time that we've utilized it, we are hesitant to draw definitive conclusions from this analysis. That said, LEARN estimates that forests and trees

[43] See https://www.mrlc.gov/.

throughout Albemarle County—in net—removed approximately 946,000 metric tons of carbon dioxide equivalent (tCO_2e) from the atmosphere every year between 2008 and 2016—primarily due to the growth of undisturbed forests and trees outside of forests.

Land development and other activities across the county landscape result in constant changes to land cover—with incremental forest losses and gains occurring simultaneously. During the analysis period, land conversions *from* forests to non-forest lands and other forest disturbances (which produce emissions) have generally outweighed conversion *to* forest lands (which sequester greenhouse gases). This implies a gradual loss of forest over time, which will result in a drop over time of the net amount of carbon being sequestered or removed from the atmosphere.

As an analogy, the amount of forest and trees in the landscape can be thought of as a principal of money in a financial stock and carbon sequestration can be thought of as dividends generated by the principal. The incremental gains and losses in forested land cover can be thought of as deposits and withdrawals to the stock. In this scenario, there have been more withdrawals than deposits during the eight-year analysis period. Consequently, future dividends—while still significant—will be lower than those in past.

Albemarle County's Climate Action Plan (2020) states, "Since carbon sequestration occurs naturally and continually, our greenhouse gas inventory will only consider new practices that remove carbon from the atmosphere, like planting new trees and agricultural practices that regenerate soil health."

Because the existence and growth of forests in central Virginia is a natural process—and not the outcome of deliberate climate action—the resulting net carbon sequestration cannot be considered as progress made towards greenhouse gas reduction targets. Nonetheless, the magnitude of the sequestration potential of local forests, trees, and other ecosystems emphasizes the importance of protecting these resources—to preserve their sequestration potential, to prevent large amounts of unnecessary emissions from forest loss, and for the many other benefits of healthy local forests.

Appendix B: GPC Reporting Information

Albemarle County: General Data

Albemarle County has a total land area of 726 square miles (1,880 km^2). In 2018, the US Census Bureau estimated the County's population at 108,377.[44] The US Bureau of Economic Analysis reported a combined Gross Domestic Product (GDP) of $10.66 billion in 2018 together for Albemarle County and the City of Charlottesville.[45] As of 2014 (most recent available data), the US Census Bureau estimated that 31,948 people employed in Albemarle County commuted in from residences in other jurisdictions, while 26,811 residents of Albemarle County commuted outside the County for work elsewhere. At the time, 16,914 people both lived and worked in Albemarle County.[46]

Greenhouse Gas Emission Summary by Scope and GPC Reporting Level[47]

Sector	Total by Scope (tCO_2e)			Total by city-induced reporting level (tCO_2e)	
	Scope 1	Scope 2	Scope 3	BASIC	BASIC+
Transportation	730,151	169	Not estimated	730,320	730,320
Stationary Energy	129,962	428,305 -169	Not estimated	558,098	558,098
Waste	Not estimated*		59,006*	59,006	59,006
AFOLU	71,943				71,943
Total				1,347,424	1,419,367

*Waste emissions include Scope 1 and Scope 3 but are not disaggregated by scope due to lack of data. Most emissions likely fall into Scope 3, so we place the number in that column.

[44] United States Census Bureau, "Annual Estimates of the Resident Population for Counties: April 1, 2010 to July 1, 2019," Virginia, County Population Totals: 2010-2019, accessed February 23, 2021, https://www.census.gov/data/tables/time-series/demo/popest/2010s-counties-total.html.
[45] US Bureau of Economic Analysis, "Gross Domestic Product by County, 2019," December 9, 2020, accessed February 2, 2021, https://www.bea.gov/news/2020/gross-domestic-product-county-2019. Note: The amount $10,664,400,000 is reported in real dollars for 2012. The Bureau of Economic Analysis only reports one GDP value for Albemarle County and the City of Charlottesville; disaggregated values for each are not available. However, Albemarle County's GHG inventory does not include the City of Charlottesville, which is outside its geographic boundary. These numbers are provided as general information about Albemarle County.
[46] Virginia Employment Commission, "Virginia Community Profile: Albemarle County," last updated November 11, 2020, accessed February 1, 2021, https://virginiaworks.com/Portals/200/Local%20Area%20Profiles/5104000003.pdf.
[47] See: World Resources Institute, C40 Cities, and ICLEI Local Governments for Sustainability, *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities* (World Resources Institute, 2014), https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf, 42.