Technical Note: Methods for estimating community-scale sectoral data from national and regional statistics for the purpose of greenhouse gas accounting and climate action planning

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Introduction

Cities account for more than 70 percent of the world's greenhouse gas (GHG) emissions and must make deep reductions in those emissions if the world is to meet and exceed its commitment under the Paris Agreement to reduce emissions in the world economy and mitigate climate change (UN 2019). Communities of all sizes, including cities, must implement meaningful changes in infrastructure, policy, and behavior, while continuing to meet the growing needs and aspirations of their residents and businesses. While some standards provide guidelines for communities on how to measure and report on their emissions, they are not intended to provide them with the actual sets of data or community-specific emission factors that they can use to bridge this gap between having data and understanding their emissions, finding best practices, and planning their actions.

Cities and other communities often cite poor quality, inaccessible, and missing local activity data and GHG emission factors as being among their top data challenges (USCOM 2016). They often lack the technical knowledge, staff, or resources to measure or compile local data useful in determining community-level GHG emissions – referred to throughout as "community-scale data". This data constraint affects communities' ability to prioritize their best opportunities for climate action and results in wasteful efforts to increase precision of baselines, slowing urban climate action.

These data can be made more readily available. National agencies and ministries in many countries have the authority and capability to collect data on key emission sources such as transportation, electricity generation, and major stationary sources. In addition, national data collection often uses standardized methods and represents the full national geography and, if tailored to community-level activities, can ensure methodological consistency in boundaries, units, and assumptions, making community-level comparisons more robust.

To explore solutions for communities, World Resources Institute (WRI), partnered with the Global Covenant of Mayors for Climate & Energy (GCoM). A series of sector-specific methodologies was developed that rely on national and regional sectoral statistics and community contextual data to develop community-scale sectoral data estimates. These estimates will allow a community to generate a GHG inventory and begin fact-based climate action planning. Emissions factors, primarily default national or international factors, were also compiled that are relevant to a city's geography or circumstances. This research provides default data or proxy data that can be used to fill gaps where primary data are not collected or available. As an approximation of what community-specific data might be, these data can be used as a starting point for more accurate and community-specific data collection. These data will be made freely available and open for use to communities through an online database: (http://dataportalforcities.org/).

This technical note describes the processes and methods for estimating the community-scale data, as well as the detailed methodologies for the United States. Additional methodological appendices are planned on a rolling basis for Canada, Mexico, Denmark, Brazil, Chile, Costa Rica, Japan, India, Indonesia, and the Philippines, among others.

1. Data Scope

The collected and estimated data are intended to provide the activity data and relevant emission factors and assumptions necessary for a community-scale greenhouse gas (GHG) inventory as defined by the Global Covenant of Mayors Common Reporting Framework (CRF) (Table 1). The GHG portion of the CRF reporting framework is built upon the Baseline Emission Inventory Guidebook (Bertoldi 2018), used by the European Covenant of Mayors for Climate & Energy, and the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (Wee Kean F. et al 2014), used by the Compact of Mayors.[1]

Both refer to the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC 2006). The framework was developed by a team of multi-disciplinary experts from GCoM partners with the aim of providing a harmonized definition of common reporting requirements across mitigation, adaptation, and energy access pillars that communities report as part of their commitment to the GCoM.

BOX 1 – Defining GHG accounting terms.

Activity data is a quantitative measure of a level of activity that results in GHG emissions taking place during a given period of time (e.g., volume of gas used, kilometers driven, tonnes of solid waste sent to landfill, etc.). **An emission factor** is a measure of the mass of GHG emissions relative to a unit of activity. For example, estimating CO2 emissions from the use of electricity involves multiplying data on kilowatt-hours (kWh) of electricity used by the emission factor (kgCO2/kWh) for electricity, which will depend on the technology and type of fuel used to generate the electricity.

Source: Wee Kean F. et al. 2014. "Chapter 5, Overview of Calculating GHG Emissions." In *Global Protocol for Community-scale Greenhouse Gas Emission Inventories* (GPC).

BOX 1

This research explores data downscaling methodologies for three of the required sectors in the emissions reporting framework of the CRF: Buildings / Stationary Energy, Transportation / Mobile Energy, and Waste (non-energy). These sectors can represent between 80 to 90 percent, on average, of reported emissions by cities (CDP 2018). The framework also notes in Section 3.3 two sectors— Industrial Processes and Product Use (IPPU), and Agriculture, Forestry and Other Land Use (AFOLU) — that are not mandatory but should be reported if they are significant. Given the nature of these sectors under the CRF framework and the inherent challenges of data availability and estimation methodologies, WRI did not pursue the development of methodologies for these two sectors at this time. This CRF requirements for GHG reporting serve as the foundation of the type of activity data and emission factors necessary to comply with it.

TABLE 1 – GHG Inventories Reporting Framework – Global Covenant of Mayors f Common Reporting Framework

Building / Stationary Energy		Fossil fuels	Grid-supplied energy	Description
Residential buildings		✓	✓	All GHG emissions from fuel combustion in stationary sources within the city boundary, consumption of grid-supplied energy consumed within the city boundary and fugitive emissions within the city boundary. GHG emissions from sources covered by a regional or national emissions trading program should be identified.
Commercial building and facilities		✓	✓	
Institutional buildings and facilities		✓	✓	
Industry	Non-Emission trading system (ETS) (or similar)	✓	✓	
	ETS (or similar)	✓	✓	
Agriculture		✓	✓	

Fugitive emissions	✓		
Transportation / Mobile Energy	**Fossil fuels**	**Grid-supplied energy**	
On-road	✓	✓	All GHG emissions from fuel combustion and use of grid-supplied energy for transportation within the city boundary. In case waterborne navigation, aviation and off-road not occurring, the notation key Not Occurring (NO) shall be used, where they are not significant the notation key NO may be used. Road and rail travel should additionally be disaggregated by municipal fleet, public transport and private and commercial transport. Cities may use the Fuel sales, Geographic (Territorial), Resident activity and City-induced methodologies to estimate activity.
Rail	✓	✓	
Waterborne navigation	✓	✓	
Aviation	✓	✓	
Off-road	✓	✓	
Waste (non-energy)	**Waste generated**		
Solid waste	✓		All GHG emissions from disposal and treatment of waste generated within the city boundary. Where waste is used for energy generation, emissions do not need to be reported here. Instead, the notation key Included Elsewhere (IE) should be used. If a treatment type is not applicable, the notation key NO shall be used.
Biological waste	✓		
Incinerated and burned waste	✓		
Wastewater	✓		

Note: Notational Keys indicate for each sector whether it was Estimated, Not Estimated (NE), the activity is Not Occurring (NO), or the activity estimate is Included Elsewhere (IE) – as in folded into another subsector .

Source: Global Covenant of Mayors. 2018. "Annex B: GHG Inventories Reporting Framework" in *Common Reporting Framework, version 6.1*.

1.1 Community Jurisdiction and Accounting Boundary

Consistent with currently recognized best practice in community-scale GHG accounting, including the GPC, the methodology described here incorporates methods for both in-boundary emissions—that is, activities resulting in emissions occurring within a city's geographic boundaries—as well as emissions occurring outside a city's boundary that are the result of community activities. Reported activity data may thus represent in-boundary activities—such as fuel consumption for in-boundary transportation—as well as out-of-boundary activities—such as waste treatment. Similarly, relevant emission factor data may correspond to energy intensity or grid data specific to a city, or to the surrounding region, depending on the area covered by the activity data.

Therefore, it is necessary to define the community entity for which data would be estimated. This definition relies on geographic boundaries identifying the spatial dimension or physical perimeter of individual communities. These boundaries align with the administrative boundaries of local or municipal governments, as defined by each specific national government. This is to ensure the disaggregation or estimation of data correspond to individual, incorporated community entities that have the authority to report a community-scale inventory and act upon the information. In instances where an administrative seat of government sits within another seat of government – for example, cities that reside within counties in the United States – only a single, consistent level of local government is chosen for an entire country that, again, aligns with how each specific national government defines that local level of government.

2. Methods

From this CRF inventory reporting framework, WRI developed a research method to identify and develop calculations and data sets for estimating community-scale data relevant to a GHG inventory. As laid out in the following sections, WRI established a research approach, convened a technical advisory group, and established several sets of criteria for assessing data and methods.

2.1 Research Approach

The following steps were taken to identity, assess, and select possible calculation methods for estimating community-scale activity data and selecting relevant emission factors and other assumptions:

- Establishing a technical advisory group consisting of relevant global experts to discuss and review the development of the methodologies.
- Conducting a landscape assessment of relevant GHG accounting methodologies and reporting platforms, and alignment with the CRF, as well as data-scaling and estimation methodologies, that support a community-scale GHG inventory across the relevant GCoM reporting sectors.
- Establishing criteria for selecting methodologies and assumptions to support the estimations.
- Identifying and filling any necessary methodological gaps based on review of relevant theoretical methods and field studies.
- Establishing tables of community-scale activity data, emission factors, and other relevant information necessary for the identified estimation methodologies.
- Establishing a set of criteria for assessing national sectoral statistics and community contextual statistics suitable for the estimation methodologies.
- Conducting data assessments of individual countries to identify existing national data sources suitable for the estimation methodologies.
- Testing data outputs by comparing against measured or reported community-scale data to calibrate the methodology and describe the uncertainty and limitations.
- Documenting country-specific methodologies and data sources.

2.2 Technical Advisory Group

WRI assembled a Data Technical Advisory Group, comprising members of the GCoM Data Technical Working Group. The members represented multiple organizations with relevant expertise in community-scale accounting and are important stakeholders in defining standardized methods to support communities. The organizations represented in the advisory group included:

- World Resources Institute (WRI)
- Global Covenant of Mayors for Climate & Energy (GCoM)
- ICLEI: USA
- C40 Cities Climate Leadership Group
- Joint Research Centre of the European Commission

WRI facilitated a series of meetings with the advisory group to review the research approach, methodology assessment, compliance with accounting best practice, and draft country methodology for the United States. Feedback from the advisory group was incorporated into the methods.

2.3 Methodology Assessment and Criteria

WRI appreciates that there can and should be several methods and data sources that are valuable to communities for informing climate action planning. Thus, WRI conducted a methodological landscape assessment to identify and compile methods and data fields that would be appropriate for the required sectoral estimates. In order to estimate , sectoral activity data appropriate for a community-scale GHG inventory, WRI first assessed the applicable *GHG accounting methodologies*—which are methods and equations that require activity data figures, emission factors, and other assumptions to calculate GHG emissions—as well as *data estimation methodologies*—which are methods and equations for scaling, disaggregating, or estimating community-scale activity data from other statistics that ultimately are entered into the GHG accounting equations. The combination of both types of equations establishes the list of community-scale activity data fields, emission factors, and assumptions provided to communities (See Appendix A) as well as the national and regional input data and community contextual data necessary for developing estimation methodologies (described in the specific sectoral methodologies for the United States in Appendix B).

Assessment of GHG Accounting Methodologies

In the assessment of appropriate GHG accounting methodologies, WRI considered and applied the following GHG accounting principles adapted from the GHG Protocol GPC standard:

- **Relevance**: The reported GHG emissions shall appropriately reflect emissions occurring as a result of activities and consumption patterns of the city. The inventory will also serve the decision-making needs of the city, taking into consideration relevant local, subnational, and national regulations. The principle of relevance applies when selecting data sources and determining and prioritizing data collection improvements.
- **Completeness**: Communities shall account for all required emissions sources within the inventory boundary. Any exclusion of emission sources shall be justified and clearly explained. Notation keys shall be used when an emission source is excluded, and/or not occurring.
- **Consistency**: Emissions calculations shall be consistent in approach, boundary, and methodology. Using consistent methodologies for calculating GHG emissions enables meaningful documentation of emission changes over time, trend analysis, and comparisons between communities. Calculating emissions should follow the methodological approaches provided by the GPC. Any deviation from the preferred methodologies shall be disclosed and justified.
- **Transparency**: Activity data, emission sources, emission factors, and accounting methodologies require adequate documentation and disclosure to enable verification. The information should be sufficient to allow individuals outside of the inventory process to use the same source data and derive the same results. All exclusions shall be clearly identified, disclosed and justified.
- **Accuracy**: The calculation of GHG emissions shall not systematically overstate or understate actual GHG emissions. Accuracy should be sufficient enough to give decision makers and the public reasonable assurance of the integrity of the reported information. Uncertainties in the quantification process shall be reduced to the extent that it is possible and practical.

WRI relied heavily on internationally recognized frameworks such as the GHG Protocol, the Global Protocol for Community-scale GHG Emissions Inventories (GPC), the EU Covenant of Mayor Climate & Energy Reporting Guidelines (EU Covenant of Mayors 2016), the ICLEI Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (ICLEI USA 2013), and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[2]. This also included a review of a version of the C40 CIRIS accounting tool (C40 2018) and the ICLEI ClearPath accounting and reporting platform (ICLEI 2018).

Additional insights and recommendations are included from academic literature, cases studies, and reports from leading organizations in the realm of community-scale greenhouse gas accounting.

Emissions data can be inventoried according to one of two complementary approaches(GPC 2014):

1. The **scopes framework** categorizes the emission sources attributable to a community into in-boundary sources (Scope 1grid-supplied energy, heat, steam, or cooling in-boundary sources (Scope 2), and out-of-boundary sources (Scope 3).
2. The **community-induced framework** allows for the comprehensive reporting of all GHG emissions attributable to activities taking place within a city's geographic boundary. These are organized by relevant community sectors, such as Building Energy, Transport, and Waste for the EU Covenant of Mayors Climate and Energy Reporting Guidelines. The GPC accounting framework, alternatively, provides two reporting levels demonstrating different levels of completeness. The BASIC level covers emission sources that occur in almost all communities (Stationary Energy, in-boundary transportation, and in-boundary generated waste) and the calculation methodologies and data are more readily available. The BASIC+ level has a more comprehensive coverage of emissions sources (BASIC sources plus Industrial processes and product use (IPPU); Agriculture, forestry, and other land use (AFOLU); transboundary transportation, and energy transmission and distribution losses) and reflects more challenging data collection and calculation procedures.

In considering these frameworks, a combination of the above-mentioned approaches is required depending on the emissions sector and subsector. For example, within the energy sector, a scopes framework is useful in describing building electricity use (e.g. kWh of electricity consumed), because at least some if not all electricity may be generated outside the community boundary. A city-induced framework is useful when thinking about solid waste, because it is important to distinguish between waste generated inside and outside a community relative to the amount of that waste imported and exported from the community for processing. In this instance, defining the appropriate scope is challenging, but some estimate of solid waste generated by the population and operations within the boundary is possible, regardless of where it is transported for processing. It was also acknowledged that the choice of method may further depend on country-specific data availability and established scope of the community inventory.

Criteria for the Assessment of Estimation Methodologies

The use of estimation methodologies is required in cases where the best available activity data do not align with the territorial or administrative boundary of a city, the data are not disaggregated into the sub-categories necessary for the inventory, or they are otherwise incomplete. Specifically, the GPC advises the use of scaling methods when locally relevant data are not available (See Box 2).

BOX 2 – Adapting Data for Inventory Use through a Scaling Methodology

In the simplest terms, a scaling methodology uses sectoral statistics that represent a larger geographic area—for downscaling—or a representative intensity figure of a subset of a community geographic area—for upscaling—in addition to a *scaling factor* (See Equation A). The scaling factor must consider the same geographic scale for the desired community estimate, the available community contextual information, and the available sectoral statistics.

Equation A

$$\text{Scaled activity data} \quad = \text{Available activity data} \quad \times \text{Scaling factor} \left(\frac{\text{Factor}_{\text{Scaled level}}}{\text{Factor}_{\text{Available level}}} \right)$$

Data may be scaled upward or downward depending on the input data being used. Very often, national or regional sectoral data must be scaled down to a community-scale--e.g., using a city's population data relative to national totals to estimate its landfill emissions. In other cases, data may need to be scaled up, such as when quality, representative survey data are available for only a subset of a city's transportation activity.

Population data often serve as an appropriate basis for a scaling factor, particularly for sectors where the number of people is a key driver of emissions and therefore correlates strongly with emissions. In other cases, other contextual data and statistics may serve as appropriate data for scaling factors—e.g., vehicle statistics, building stock, and economic indicators.

Source: Wee Kean F. et al. 2014. "Section 5.3.1, Scaling Methodology." In *Global Protocol for Community-scale Greenhouse Gas Emission Inventories* (GPC).

[**BOX 2 end]**

The choice of estimation methodology—and related contextual data for scaling factors—may vary depending on sector, data availability, and country context. However, an appropriate approach should generally represent a well-documented relationship between available sectoral input data and the required community-scale output data. In the assessment and selection of sectoral estimation and downscaling methodologies, WRI applied the following criteria:

- Availability: For both sectoral input data and contextual data required for scaling factors, the methodology should rely on data that are readily available and do not need to be created.
- Relevance: The methodology should rely on sectoral input data that relate to appropriate activities leading to relevant emissions sectors and subsectors. In addition, the scaling factors should be correlated to the sectoral input data—e.g., the use of residential population and building stock statistics for residential energy consumption.
- Completeness: The methodology should rely on sectoral input data that includes full data for a specific activity across all relevant community jurisdictions, with exclusion clearly documented—e.g., country-level sectoral statistics that include all community activity for all communities in the country. The sectoral input data should also represent complete years of data, rather than a partial year, even if it covers no more than one recent year. For time-series data, methods and assumptions should be consistent.
- Quality: For both sectoral input data and contextual data required for scaling factors, the methodology should rely on data that come from credible, reputable sources, preferable national or regional statistics reported by national governments or affiliated research institutions. These data should include documentation on methods of collection or creation and should be updated and corrected regularly.

Specific estimation methodologies were chosen for each country based on, first, a methodology assessment that revealed the variety of existing calculations methods, and, second, the outcomes of a country data assessment (Section 2.4)—i.e., what sectoral input data exist within a specific country. Combined, this creates a country-specific methodology, which is documented individually for each country. The methodology for the United States is presented in Appendix B. Further appendices for other countries will be made available as they are developed.

2.4 Country Data Assessment

Country-specific research began with a thorough landscape review and assessment of existing sectoral input data (national or regional in scale) and community contextual data necessary for the sector-specific data estimation methodologies. Table 2 illustrates example data sets sought.

TABLE 2 – Country-specific Contextual and Sectoral Input Data Assessment

Category	Data Examples	Data Sources
Contextual Data	Name of local authority Country Geographic boundary Resident population Building Stock Employee Statistics Vehicle Registration Statistics Income GDP	National census or other national survey data National economic/commerce statistical agencies National building registries Building energy efficiency and usage surveys
Buildings & Stationary Energy Sector	Electricity grid consumption/sales data Fuel (non-electricity) consumption/sales data Energy production data Map data for building types	National energy statistical agencies Energy research institutes
Transportation & Mobile Energy Sector	Fuel consumption/sales data Vehicle fuel intensity data Roadway, rail, waterborne, and freight and mileage data Transportation survey and trip data Road segment data	National energy statistical agencies National transit authorities National transportation statistical agencies
Waste (non-energy) Sector	Mass of waste Composition of solid waste Treatment types and proportions Volume of wastewater treated Methane recovery rates	National Environmental Agencies Waste Management Facilities Regional Waste Composition Surveys Waste Management Facility Data

Each country presents a unique challenge based on the available data. WRI conducts a review of available national, regional, and community inventories for the identified country. These inventories highlight the available data sources and provided insight into priority subsectors within the country based on the magnitude of emissions. After identifying potential available data sources, WRI seeks to obtain the data through publicly available databases. Where data are not readily available online or from other public sources, WRI engages directly with data owners, including government ministries. Where data gaps are identified, WRI works with the national or regional government stakeholders to assess data availability and alternatives. WRI then assesses the quality of the available data based on the accounting principles highlighted above and suitability with the identified estimation methodologies. WRI gives preference to data sets updated annually and maintained by a reputable source, such as a government agency, that has documented quality control and source information. Relevant government sources include energy ministries, transportation ministries, environment ministries, housing ministries, and government-run open data portals.

In specific instances where temporal, geographic, or other gaps exist in the data, WRI follows a similar process to the methodology assessment to fill the gaps. WRI identifies appropriately correlated proxy data for each subsector, and then uses the trends in the proxy data to approximate missing data. The specific sectoral input data, community contextual data, data estimation methodologies, and gap fill procedures were documented in country-specific methodologies (See Appendix B).

3. Results

3.1 Community-Scale Data Tables

Through the identification of GHG accounting methodologies and data estimation methodologies, WRI catalogued necessary and relevant community-scale activity data fields, community-relevant emission factors, and other assumptions that would support the creation of a community-scale GHG inventory. These tables are organized in three broad categories. The “City Contextual Data” are existing data on communities within a specific country necessary to inform scaling factors. The “Sectoral Data” tables represent the community-scale outputs of the estimation methodologies. The “Emission Factor and Other Assumptions” represent existing regional, national, or international defaults that are acceptable for use in a community-scale inventory. Appendix A provides the full data field tables organized by the following categories and subcategories:

- City Contextual Data
- Sectoral Data
    - Buildings & Stationary Energy
        - Stationary Energy
        - Fugitive Emissions (for natural gas distribution)
        - Energy Generation
    - Transportation & Mobile Energy
        - On-Road Vehicles
        - Rail
        - Aviation
        - Waterborne
        - Off-Road Vehicles
    - Waste
        - Solid Waste
        - Biological Treatment of Solid Waste
        - Incineration and Open Burning
        - Domestic Wastewater Treatment
- Emission Factors and Other Assumptions

- Stationary and Mobile Energy Emission Factors
- Electricity Grid Emission Factors
- Purchased Energy Emission Factors
- Solid Waste Assumptions
- Biological Treatment of Solid Waste Assumptions
- Incineration and Open Burning Assumptions
- Domestic Wastewater Treatment Assumptions

A complete list can be found in the documentation of country-specific estimation methodologies (Appendix B). Country-specific sectoral input data are also included in the country-specific methodologies.

3.2 Country-Specific Methodologies and Data: United States

Based on the methodology assessments and country data assessments, Table 3 outlines sectors and subsectors for which community-scale activity data could be estimated for United States. In addition, relevant emission factors and other assumptions are included for each sector. Necessary sectoral input data and contextual data were available to estimate building and stationary energy for all subsectors except for Municipal, which could not be disaggregated from other Commercial building energy consumption. Therefore, data for that subsector are under Commercial. Regarding Fugitive Emissions, there were insufficient data on oil and gas operations, or consistent leakage data from natural gas distribution, in community geographies to estimate these values. Transboundary issues associated with location and use of equipment and fuel did not allow for an estimate of activity data for waterborne or rail transportation. Lastly, incineration and open burning of waste is not a common practice in the United States. Hence, this emission category is not estimated in light of insufficient data. For more detail, refer to Appendix B.

TABLE 3 – Estimated Community-Scale Activity Data for the United States by Inventory Subsector

Buildings and Stationary Energy Sector	
Residential buildings	Included
Commercial buildings	Included
Municipal buildings	Not separately estimated (Included in Commercial buildings)
Industry	Included
Agriculture, forestry and fisheries	Included
Fugitive emissions	Not currently estimated
Energy Generation	Not currently estimated
Transportation and Mobile Energy Sector	
On-road	Included
Rail	Not currently estimated
Waterborne navigation	Not currently estimated
Aviation	Included
Off-road	Included

Waste Sector	
Solid Waste	Included
Biological Treatment of Waste	Included
Incineration and Open Burning	Not currently estimated
Domestic Wastewater	Included

4. Conclusions and Practical Application

In instances where the locally appropriate activity data do not exist or cannot be estimated from existing local source, the GPC allows for the use of scaling methodologies to estimate community-level activity data from other available activity data at a different geographic level and community-specific contextual data. Based on this guidance, WRI applies scaling methodologies across sectoral data at national or regional levels to estimate community-level data across several communities for a particular country. In this effort, WRI identified a standard set of data fields required by a community to support a community-scale inventory across three sectors – Buildings and Stationary Energy, Transportation and Mobile Energy, and Waste – as well as calculation methodologies to accomplish the scaling through a combination of community contextual data and sectoral input data aggregated above the community level. Within the United States, these calculations produced estimates of community-scale activity data across 12 subsectors within the three sectors for over 22,000 community locations. These are accompanied by locally relevant emission factors and other assumptions to support a community-scale inventory.

The estimates produced by these methods are intended to provide default data or proxy data that can be used to fill gaps where primary data are not collected or available. It is an approximation of what community-specific data might be, which can be used as a starting point for more accurate and community-specific data collection. It can be used as an initial screening step to get a sense of where higher emitting sectors or sources in the community are likely to be. These methods are not intended to replace local measurement of activity data or greenhouse gas emissions, which are considered the best available data for communities. In addition, the estimates from these methods should not yet be used for local target-setting or tracking performance of community policies or progress toward community targets. While these data can provide an annual proxy for the years that are available, the data are not community-derived and therefore will not reflect changes based on implementation of actions taken to alter activities.

<u>The goal of these methods is inherently to estimate data that do not already exist</u>. Therefore, it is difficult to compare against enough available measured data to evaluate and calibrate the methods or describe a range of uncertainty. Additional refinement of the methods is necessary through detailed comparisons with measured and reported community data and additional community-specific context that influence activity data in ways that are unique to specific community circumstances. Until that point, these methods can still provide communities an approximate understanding of their context regarding multiple sectors and begin to inform the prioritization of climate action and local measurement.

Beyond this stated purpose, communities and researchers may find additional value from these data. For example, the estimated sectoral activity data and locally relevant emission factors could be combined to provide first-tier estimates of GHG emissions in the sectors that often contribute the most emissions for a community, on average. Such an initial footprint can allow communities to take further steps in climate action planning. In addition, beyond a single community focus, insight could be gained through analyses of individual subsector estimates across all communities in one country, or relative comparisons between subsectors with geospatial resolution. The application of a standardized methodology allows for such comparisons. This broadens the range of potential application from hot-spot analysis and sectoral planning to global finance and peer-network building. It is WRI's hope that additional work here will reveal these and other applications of this research.

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Appendix A – Community-scale Data Tables

The following tables include all the relevant community-scale activity data, emission factors, and other assumptions identified as necessary to complete a community-scale GHG inventory. These potentially apply to all countries, while Appendix B is specific to the United States. These are data needs informed by the identified data estimation methodologies and available sectoral input data and community contextual data. The "City Contextual Data", Table A1, lists the types of existing data on communities within a specific country that provide context and can help develop scaling factors. The "Sectoral Data" tables list the community-scale outputs of the estimation methodologies. The "Emission Factor and Other Assumptions" table lists existing regional, national, or international defaults that are acceptable for use in a community-scale inventory.

TABLE A1. City Contextual Data Fields

Field Name	Allowable Values
Total Area Value	Number
Total Area Unit	Square Miles (mi^2) Square Kilometers (km^2)
Land Area Value	Number
Land Area Units	Square Miles (mi^2) Square Kilometers (km^2)
Water Area Value	Number
Water Area Units	Square Miles (mi^2) Square Kilometers (km^2)
Population	Number
City Type	Urban High/Low Income Rural
Dominant Wastewater Infrastructure	Septic Sewer Latrine Other
Gross Domestic Product	USD (or national currency)
Median Household Income	USD (or national currency)
Regional Association	Text
Estimated Total Building Area Value	Number
Estimated Total Building Area Units	Square feet (ft^2) Square meters (m^2)
Estimated Residential Building Area Value	Number
Estimated Residential Building Area Units	Square feet (ft^2) Square meters (m^2)
Estimated Commercial Building Area Value	Number
Estimated Commercial Building Area Units	Square feet (ft^2) Square meters (m^2)
Estimated Industrial Building Area Value	Number
Estimated Industrial Building Area Units	Square feet (ft^2) Square meters (m^2)

Field Name	Allowable Values
Estimated Municipal Building Area Value	Number
Estimated Municipal Building Area Units	Square feet (ft^2) Square meters (m^2)
Airport Volume - Passengers per year	Number
Airport Volume - Freight per year	Number
Airport Volume - Payload per year	Number
Length of Railway Tracks Value	Number
Length of Railway Tracks Unit	Miles (mi) Kilometers (km)
Length of Roads Value	Number
Length of Roads Unit	Miles (mi) Kilometers (km)
Utility Service Area – Electric	Text
Utility Service Area – Natural Gas	Text
Utility Service Area - Thermal	Text
Regional Electricity Grid	Text

Sectoral Data – Buildings and Stationary Energy

Stationary Energy

Data are collected for the following subsectors:

- Residential buildings
- Commercial buildings
- Municipal buildings
- Industrial buildings
- Agriculture, Forestry, and Fisheries buildings

Each field represents an amount of stationary energy consumed by the specific fuel type, which may be presented in energy terms or volumetric terms.

Table A2. Stationary Energy Data Fields

Data Field	Allowable Values
Grid Electricity Value	Number
Grid Electricity Unit	Megawatt-hours (MWh) Megajoules (MJ)
Coal Value	Number
Coal Unit	Megawatt-hours (MWh) Megajoules (MJ)
Natural Gas Value	Number

Natural Gas Unit	Megawatt-hours (MWh) Million Cubic Feet (MMcf) Cubic Meters (m3) Million British Thermal Units (MMBTU) Megajoules (MJ)
Total Oil Value	Number
Total Oil Unit	Gallons (g) Liters (l) Megajoules (MJ) Megawatt-hours (MWh)
Total Distillate Fuel Oil General Value	Number
Total Distillate Fuel Oil General Unit	Gallons (g) Liters (l) Megajoules (MJ) Megawatt-hours (MWh)
Total Residual Fuel Oil Value	Number
Total Residual Fuel Oil Unit	Gallons (g) Liters (l) Megajoules (MJ) Megawatt-hours (MWh)
Kerosene Value	Number
Kerosene Unit	Gallons (g) Liters (l) Megajoules (MJ) Megawatt-hours (MWh)
LPG Value	Number
LPG Units	Gallons (g) Liters (l) Megajoules (MJ) Megawatt-hours (MWh)
Total Biomass Value	Number
Total Biomass Unit	Megajoules (MJ) Megawatt-hours (MWh)
Solid Biomass Value	Number
Solid Biomass Unit	Megajoules (MJ) Megawatt-hours (MWh)
Liquid Biofuels Value	Number
Liquid Biofuels Unit	Gallons (g) Liters (l) Megajoules (MJ) Megawatt-hours (MWh)
Biogas Value	Number
Biogas Unit	Megawatt-hours (MWh) Million Cubic Feet (MMcf) Cubic Meters (m^3) Million British Thermal Units (MMBTU) Megajoules (MJ)

District Heating - Steam Value	Number
District Heating - Steam Unit	Megajoules (MJ) Million British Thermal Units (MMBTU)
District Heating - Hot Water Value	Number
District Heating - Hot Water Unit	Megajoules (MJ) Million British Thermal Units (MMBTU)
District Cooling Value	Number
District Cooling Unit	Megajoules (MJ) Million British Thermal Units (MMBTU)

Table A3. Fugitive Emissions Data Fields (limited to Natural Gas distribution)

Field Name	Allowable Values
Fugitive Natural Gas Units	Million Cubic Feet (MMcf) Cubic Meters (m3) Million British Thermal Units (MMBTU) Megajoules (MJ) MWh
Fugitive Natural Gas Value	Number
Fugitive Natural Gas Leakage Rate	Number
Fugitive Gas Units	Kilograms (kg)
Fugitive CO2 Value	Number
Fugitive CH4 Value	Number
Fugitive Gas Emission Factor Units	Kilograms (kg) of fugitive gas per unit of natural gas
Fugitive CO2 Emission Factor Value	Number
Fugitive CH4 Emission Factor Value	Number

Table A4. Energy Generation

Field Name	Allowable Values
Electricity Generation Unit	Megawatt-hours (MWh) Megajoules (MJ) Thermal Units (MMBTU) Tons of oil equivalent (toe)
Total Electricity Generation Value	Number
Coal Electricity Generation Value	Number
Natural Gas Electricity Generation Value	Number
Oil Electricity Generation Value	Number
Waste Electricity Generation Value	Number
Other Electricity Generation Value	Number
Nuclear Electricity Generation Value	Number
Solar Electricity Generation Value	Number
Wind Turbine Electricity Generation Value	Number
Hydroelectric Electricity Generation Value	Number
Biomass Electricity Generation Value	Number

Geothermal Electricity Generation Value	Number
Electricity Transmission & Distribution Loss Fraction	Number
CHP Electricity Generation Value	Number
District Heat/Cooling Generation Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Total District Heat Generation Value	Number
Coal District Heat Generation Value	Number
Natural Gas District Heat Generation Value	Number
Oil District Heat Generation Value	Number
Waste District Heat Generation Value	Number
Other District Heat Generation Value	Number
Biomass District Heat Generation Value	Number
Geothermal District Heat Generation Value	Number
District Heat Generation Loss Fraction	Number
CHP District Heat Generation Value	Number
Cooling Generation Value	Number
Cooling Generation Loss Fraction	Number

Sectoral Data - Transport Sector

Table A5. On-Road Fuel - Distinguished between both "Private and Commercial" and "Public" ownership

Field Name	Allowable Values
Ownership	Private and Commercial Public
All Vehicles Diesel Value	Number
All Vehicles Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
All Vehicles Gasoline Value	Number
All Vehicles Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
All Vehicles Electric Value	Number
All Vehicles Electric Unit	Megawatt-hour (MWh) Megajoules (MJ)

	Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
All Vehicles Biodiesel Value	Number
All Vehicles Biodiesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
All Vehicles Ethanol Value	Number
All Vehicles Ethanol Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
All Vehicles LPG Value	Number
All Vehicles LPG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Million cubic feet (MMcf) Cubic meters (m^3) Gallons (g) Liters (l)
All Vehicles CNG Value	Number
All Vehicles CNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Million cubic feet (MMcf) Cubic meters (m^3)
All Vehicles Other Value	Number
All Vehicles Other Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Motorcycle Gasoline Value	Number
Motorcycle Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)

Passenger Car Gasoline Value	Number
Passenger Car Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Passenger Car Diesel Value	Number
Passenger Car Diesel Unit	Gallons (g) Liters (l)
Passenger Car Electricity Value	Number
Passenger Car Electricity Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Light Truck Gasoline Value	Number
Light Truck Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Light Truck Diesel Value	Number
Light Truck Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Buses Diesel Value	Number
Buses Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Buses Electric Value	Number
Buses Electric Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Buses CNG Value	Number
Buses CNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU)

	Tons of oil equivalent (toe) Million cubic feet (MMcf) Cubic meters (m^3)
Single-Unit Truck Diesel Value	Number
Single-Unit Truck Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l) l
Combination Truck Diesel Value	Number
Combination Truck Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Moped Gasoline Value	Number
Moped Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Moped Electricity Value	Number
Moped Electricity Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)

Table A6. On-Road VMT (Vehicle Miles Traveled) - Distinguished between both "Private and Commercial" and "Public" ownership.

Field Name	Allowable Values
Ownership	Private and Commercial Public
All Vehicles VMT Value	Number
All Vehicles VMT Unit	Miles (mi) Kilometers (km)
Motorcycle VMT Value	Number
Motorcycle VMT Unit	Miles (mi) Kilometers (km)
Passenger Car VMT Value	Number

Passenger Car VMT Unit	Miles (mi) Kilometers (km)
Light Truck VMT Value	Number
Light Truck VMT Unit	Miles (mi) Kilometers (km)
Bus VMT Value	Number
Bus VMT Unit	Miles (mi) Kilometers (km)
Single-Unit Truck VMT Value	Number
Single-Unit Truck VMT Unit	Miles (mi) Kilometers (km)
Combination Truck VMT Value	Number
Combination Truck VMT Unit	Miles (mi) Kilometers (km)

Table A7. Rail

Field Name	Allowable Values
Urban Rail Electricity Value	Number
Urban Rail Electricity Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Urban Rail Diesel Value	Number
Urban Rail Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Urban Rail Biodiesel Value	Number
Urban Rail Biodiesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Urban Rail LNG Value	Number
Urban Rail LNG Value LNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Million cubic feet (MMcf) Cubic meters (m^3)
Regional Passenger Rail Electricity Value	Number

Regional Passenger Rail Electricity Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Regional Passenger Rail Diesel Value	Number
Regional Passenger Rail Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Regional Passenger Rail Biodiesel Value	Number
Regional Passenger Rail Biodiesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Regional Passenger Rail LNG Value	Number
Regional Passenger Rail LNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Million cubic feet (MMcf) Cubic meters (m^3)
Regional Freight Rail Electricity Value	Number
Regional Freight Rail Electricity Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Regional Freight Rail Diesel Value	Number
Regional Freight Rail Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Regional Freight Rail Biodiesel Value	Number
Regional Freight Rail Biodiesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Regional Freight Rail LNG Value	Number

Regional Freight Rail LNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Million cubic feet (MMcf) Cubic meters (m^3)

Table A8. Aviation

Field Name	Allowable Values
Aviation Electricity Value	Number
Aviation Electricity Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Aviation Jet Fuel Value	Number
Aviation Jet Fuel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Aviation Gasoline Value	Number
Aviation Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)

Table A9. Waterborne

Field Name	Allowable Values
Ferry Vessel Diesel Value	Number
Ferry Vessel Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Ferry Vessel Gasoline Value	Number
Ferry Vessel Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g)

	Liters (l)
Ferry Vessel CNG/LNG Value	Number
Ferry Vessel CNG/LNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Ferry Vessel Biodiesel Value	Number
Ferry Vessel Biodiesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Ferry Vessel Electric Value	Number
Ferry Vessel Electric Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Ferry Vessel Other Fuel Value	Number
Ferry Vessel Other Fuel Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Passenger and Recreational Vessel Diesel Value	Number
Passenger and Recreational Vessel Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Passenger and Recreational Gasoline Value	Number
Passenger and Recreational Vessel Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Passenger and Recreational Vessel CNG/LNG Value	Number
Passenger and Recreational Vessel CNG/LNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU)

	Tons of oil equivalent (toe) Gallons (g) Liters (l)
Passenger and Recreational Vessel Biodiesel Value	Number
Passenger and Recreational Vessel Biodiesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Passenger and Recreational Vessel Electric Value	Number
Passenger and Recreational Vessel Electric Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Passenger and Recreational Vessel Other Fuel Value	Number
Passenger and Recreational Vessel Other Fuel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Fishing Vessel Diesel Value	Number
Fishing Vessel Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Fishing Vessel Gasoline Value	Number
Fishing Vessel Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Fishing Vessel CNG/LNG Value	Number
Fishing Vessel CNG/LNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Fishing Vessel Residual Fuels Value	Number
Fishing Vessel Residual Fuels Unit	Megajoules (MJ)

	Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Fishing Vessel Other Fuel Value	Number
Fishing Vessel Other Fuel Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Shipping/Cargo Vessel Diesel Value	Number
Shipping/Cargo Vessel Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Shipping/Cargo Vessel Gasoline Value	Number
Shipping/Cargo Vessel Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Shipping/Cargo Vessel CNG/LNG Value	Number
Shipping/Cargo Vessel CNG/LNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Shipping/Cargo Vessel Residual Fuels Value	Number
Shipping/Cargo Vessel Residual Fuels Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Shipping/Cargo Vessel Other Fuel Value	Number
Shipping/Cargo Vessel Other Fuel Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)

	Gallons (g) Liters (l)
Other Vessel Diesel Value	Number
Other Vessel Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Other Vessel Gasoline Value	Number
Other Vessel Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Other Vessel CNG/LNG Value	Number
Other Vessel CNG/LNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Other Vessel LPG Value	Number
Other Vessel LPG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Other Vessel Biodiesel Value	Number
Other Vessel Biodiesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Other Vessel Residual Fuels Value	Number
Other Vessel Residual Fuels Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Other Vessel Electric Value	Number
Other Vessel Electric Unit	Megawatt-hour (MWh) Megajoules (MJ)

	Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Other Vessel Other Fuel Value	Number
Other Vessel Other Fuel Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)

Table A10. Off-Road

Field Name	Allowable Values
Off-Road Diesel Value	Number
Off-Road Diesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Off-Road Gasoline Value	Number
Off-Road Gasoline Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Off-Road Electric Value	Number
Off-Road Electric Unit	Megawatt-hour (MWh) Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe)
Off-Road Biodiesel Value	Number
Off-Road Biodiesel Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Gallons (g) Liters (l)
Off-Road Ethanol Value	Number
Off-Road Ethanol Unit	Megajoules (MJ) Million British Thermal Units (MMBTU)

	Tons of oil equivalent (toe) Gallons (g) Liters (l)
Off-Road LPG Value	Number
Off-Road LPG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Million cubic feet (MMcf) Cubic meters (m^3) Gallons (g) Liters (l)
Off-Road CNG Value	Number
Off-Road CNG Unit	Megajoules (MJ) Million British Thermal Units (MMBTU) Tons of oil equivalent (toe) Million cubic feet (MMcf) Cubic meters (m^3)

SECTORAL DATA - WASTE

Table A11. Waste Composition

Field Name	Allowable Values
Waste Mass Unit	Metric Tons (t)
Municipal Solid Waste – Mass Value	Number
Industrial - Mass Value	Number
Sewage sludge - Mass Value	Number
Sludge Non-sewage – Mass Value	Number
Clinical - Mass Value	Number
Fossil liquid fuel - Mass Value	Number
Food – MSW Fraction	Number
Garden – MSW Fraction	Number
Paper and paperboard - MSW Fraction	Number
Wood and straw - MSW Fraction	Number
Textiles - MSW Fraction	Number
Nappies - MSW Fraction	Number
Rubber and leather - MSW Fraction	Number
Plastics - MSW Fraction	Number
Metal - MSW Fraction	Number
Glass - MSW Fraction	Number
Other, inert - MSW Fraction	Number

Table A12. Solid Waste Landfill Disposal

Field Name	Allowable Values
Landfill Waste – Units	Metric Tons (t)
Managed Landfill Waste – Total Mass Value	Number
Unmanaged Landfill Deep - Total Waste Mass Value	Number
Unmanaged Landfill Shallow - Total Waste Mass Value	Number
Uncategorized Landfill - Total Waste Mass Value	Number
Landfill Methane Recovery Fraction	Number
Landfill Methane Generation Potential Unit	Metric Ton Methane per Metric Ton of MSW (tCH_4/t)
Landfill Methane Generation Potential Value	Number

Table A13. Solid Waste Recycled

Field Name	Allowable Values
Recycled Waste Mass Units	Metric Tons (t)
Recycled Waste Mass Value	Number
Paper and paperboard - Recycled Mass Value	Number
Metal - Recycled Mass Value	Number
Plastics - Recycled Mass Value	Number
Rubber and leather - Recycled Mass Value	Number
Textiles - Recycled Mass Value	Number
Other materials - Recycled Mass Value	Number

Table A14. Biological Treatment of Solid Waste

Field Name	Allowable Values
Biological Waste – Units	Metric Tons (t)
Biological Waste – Compost - Total Mass Value	Number
Biological Waste – Anaerobic Digestion - Total Mass Value	Number
Methane Recovery Fraction	Number

Table A15. Incineration and Open Burning of Waste

Field Name	Allowable Values
Incinerated or Burned Waste – Mass Units	Metric Tons (t)
Incinerated Waste – Total Mass Value	Number
Burned Waste – Total Mass Value	Number
Municipal Solid Waste - Continuous Incineration – Stoker – Wet Mass Value	Number
Municipal Solid Waste - Continuous Incineration – Fluidized Bed – Wet Mass Value	Number
Municipal Solid Waste - Semi-Continuous Incineration – Stoker – Wet Mass Value	Number

Municipal Solid Waste - Semi-Continuous Incineration – Fluidized Bed – Wet Mass Value	Number
Municipal Solid Waste - Batch-type Incineration – Stoker – Wet Mass Value	Number
Municipal Solid Waste - Batch-type Incineration – Fluidized Bed – Wet Mass Value	Number
Municipal Solid Waste – Open Burning – Dry Mass Value	Number
Industrial Waste - Continuous Incineration – Stoker – Wet Mass Value	Number
Industrial Waste - Continuous Incineration – Fluidized Bed – Wet Mass Value	Number
Industrial Waste - Semi-Continuous Incineration – Stoker – Wet Mass Value	Number
Industrial Waste - Semi-Continuous Incineration – Fluidized Bed – Wet Mass Value	Number
Industrial Waste - Batch-type Incineration – Stoker – Wet Mass Value	Number
Industrial Waste - Batch-type Incineration – Fluidized Bed – Wet Mass Value	Number
Sludge Non-Sewage - Continuous Incineration – Stoker – Wet Mass Value	Number
Sludge Non-Sewage - Continuous Incineration – Fluidized Bed – Wet Mass Value	Number
Sludge Non-Sewage - Semi-Continuous Incineration – Stoker – Wet Mass Value	Number
Sludge Non-Sewage - Semi-Continuous Incineration – Fluidized Bed – Wet Mass Value	Number
Sludge Non-Sewage - Batch-type Incineration – Stoker – Wet Mass Value	Number
Sludge Non-Sewage - Batch-type Incineration – Fluidized Bed – Wet Mass Value	Number
Sludge Non-Sewage – Open Burning – Dry Mass Value	Number
Clinical Waste – Incineration – Mass Value	Number
Sewage Sludge – Wet Mass Value	Number
Sewage Sludge – Dry Mass Value	Number
Fossil Liquid Waste – Incineration – Mass Value	Number

Table A16. Domestic Wastewater Treatment and Discharge

Field Name	Allowable Values
Urban Population Served	Number
Rural Population Served	Number
Organic Component Removed as Sludge - Annual Mass Value (kg BOD)	Number
Per Capita Annual Protein Consumption (kg/person)	Number
Degree of Utilization of Large Wastewater Treatment Plant	Number
Degree of Utilization – Rural Septic	Number
Degree of Utilization – Rural Sewer	Number
Degree of Utilization – Rural Latrine	Number
Degree of Utilization – Rural Other	Number
Degree of Utilization – Rural None	Number
Degree of Utilization – Urban Septic	Number
Degree of Utilization – Urban Sewer	Number
Degree of Utilization – Urban Latrine	Number
Degree of Utilization – Urban Other	Number
Degree of Utilization – Urban None	Number
Methane Recovery Fraction	Number

Emission Factors & Other Assumptions

Table A17. STATIONARY AND MOBILE FUEL EMISSION FACTORS & HEATING VALUES

Field Name	Allowable Values
Country ISO 3 Code	Text
Country Name	Text
Fuel Type	Text
Emission Factor Unit	Text
Carbon Dioxide Emission Factor Value	Number
Methane Emission Factor Value	Number
Nitrous Oxide Emission Factor Value	Number
Heating Value Mass (GJ/t)	Number
Heating Value Liquid Volume (GJ/L)	Number
Heating Value Gaseous Volume (GJ/CCF)	Number

Table A18. ELECTRICITY GRID EMISSION FACTORS

Field Name	Allowable Values
Country ISO 3 Code	Text
Country Name	Text
Grid Subregion Name	Text
Emission Factor Unit	Text
Carbon Dioxide Emission Factor Value	Number
Methane Emission Factor Value	Number
Nitrous Oxide Emission Factor Value	Number
Coal – Fraction	Number
Natural Gas – Fraction	Number
Oil - Fraction	Number
Nuclear – Fraction	Number
Waste – Fraction	Number
Biomass – Fraction	Number
Hydropower – Fraction	Number
Wind – Fraction	Number
Solar PV – Fraction	Number
Geothermal – Fraction	Number
Other - Fraction	Number

Table A19. PURCHASED ENERGY (THERMAL) EMISSION FACTORS

Field Name	Allowable Values
Purchased Energy Type	Steam Hot Water Chilled Water CHP All

	CHP Electricity CHP Steam CHP Hot Water
Emission Factor Unit	Text
Carbon Dioxide Emission Factor Value	Number
Methane Emission Factor Value	Number
Nitrous Oxide Emission Factor Value	Number

Table A20. Solid Waste Disposal - Degradable Organic Carbon & Carbon Content Factors

Field Name	Allowable Values
Waste Type	Food Garden Paper Wood/Straw Textiles Industrial Nappies Rubber/Leather Plastics Metal Glass Other, inert Sewage Sludge Sludge Non-sewage Clinical Fossil Liquid Fuel
Degradable Organic Carbon fraction value (DOC)	Number
Dry Matter Content in percent of wet weight	Number
Total carbon content in percent of dry weight	Number
Fossil carbon fraction in percent of total carbon content	Number
Oxidation factor in percent of carbon input – Incineration	Number
Oxidation factor in percent of carbon input – Open Burning	Number

Table A21. Solid Waste Disposal Methane Correction Factor

Field Name	Allowable Values
Landfill Characteristic	Managed Unmanaged – Deep Unmanaged – Shallow Uncategorized
Methane Correction Factor Value	Number
Fraction of Methane in Landfill Gas Value	Number
Fraction of DOC Ultimately Degraded Value	Number
Oxidation Factor	Number

Methane to Carbon Ratio	Number

Table A22. Biological Treatment of Solid Waste

Field Name	Allowable Values
Biological Waste Treatment Type	Compost Anaerobic Digestion
Emission Factor Unit	Grams of GHG per Kilogram of Waste (gGHG/kg Waste)
Biological Wet Waste - CH_4 Emission Factor	Number
Biological Wet Waste - N_2O Emission Factor	Number
Biological Dry Waste - CH_4 Emission Factor	Number
Biological Dry Waste - N_2O Emission Factor	Number

Table A23. Incineration and Open Burning of Waste

Field Name	Allowable Values
Waste-Incineration Technology Type	[See List Below]
Emission Factor Unit	Grams of GHG per Kilogram of Waste (gGHG/kg Waste)
Incinerated Waste - CO_2 Emission Factor	Number
Incinerated Waste - CH_4 Emission Factor	Number
Incinerated Waste - N_2O Emission Factor	Number

Table A24. Waste-Incineration Technology Type and Operation Mode

Waste-Incineration Technology Type and Operation Mode
Municipal Solid Waste - Continuous Incineration – Stoker – Wet Mass Municipal Solid Waste - Continuous Incineration – Fluidized Bed – Wet Mass Municipal Solid Waste - Semi-Continuous Incineration – Stoker – Wet Mass Municipal Solid Waste - Semi-Continuous Incineration – Fluidized Bed – Wet Mass Municipal Solid Waste - Batch-type Incineration – Stoker – Wet Mass Municipal Solid Waste - Batch-type Incineration – Fluidized Bed – Wet Mass Municipal Solid Waste – Open Burning – Dry Mass Industrial Waste - Continuous Incineration – Stoker – Wet Mass Industrial Waste - Continuous Incineration – Fluidized Bed – Wet Mass Industrial Waste - Semi-Continuous Incineration – Stoker – Wet Mass Industrial Waste - Semi-Continuous Incineration – Fluidized Bed – Wet Mass Industrial Waste - Batch-type Incineration – Stoker – Wet Mass Industrial Waste - Batch-type Incineration – Fluidized Bed – Wet Mass Sludge Non-Sewage - Continuous Incineration – Stoker – Wet Mass Sludge Non-Sewage - Continuous Incineration – Fluidized Bed – Wet Mass Sludge Non-Sewage - Semi-Continuous Incineration – Stoker – Wet Mass Sludge Non-Sewage - Semi-Continuous Incineration – Fluidized Bed – Wet Mass Sludge Non-Sewage - Batch-type Incineration – Stoker – Wet Mass Sludge Non-Sewage - Batch-type Incineration – Fluidized Bed – Wet Mass

Sludge Non-Sewage – Open Burning – Dry Mass
Clinical Waste – Incineration
Sewage Sludge – Wet Mass
Sewage Sludge – Dry Mass
Fossil Liquid Waste – Incineration

Table A25. Domestic Wastewater Treatment and Discharge Default Correction Factors

Field Name	Allowable Values
Industrial BOD Discharge Correction Factor	Number
Maximum Methane Producing Capacity (kg CH_4/kg BOD)	Number
Biochemical Oxygen Demand – (g/person/day)	Number
Fraction of Nitrogen in Protein (kg N/kg protein)	Number
Industrial and Commercial Co-discharged Protein Factor	Number
Discharge N_2O Emission factor (kg N_2O-N/kgN_20)	Number
Non-consumed Protein Adjustment Factor	Number
Nitrogen removed with sludge (kg N)	Number
N_2O Emission - centralized wastewater treatment plants (kg N_2O/person)	Number
The conversion of kg N_2O-N into kg N_2O	Number

Table A26. Methane Correction Factors

Field Name	Allowable Values
MCF – Non-treated Domestic (sea, river, lake)	Number
MCF – Non-treated Domestic (Stagnant Sewer)	Number
MCF – Non-treated Domestic (Flowing Sewer)	Number
MCF – Treated Domestic (Managed Treatment Plant)	Number
MCF – Treated Domestic (Unmanaged Treatment Plant)	Number
MCF – Treated Domestic (Septic System)	Number
MCF – Treated Domestic (Latrine 3-5 persons)	Number
MCF – Treated Domestic (Dry climate latrine many users)	Number
MCF – Treated Domestic (Wet climate latrine flush water use)	Number
MCF– Treated Domestic (Latrine with regular sediment removal)	Number
MCF – Treated Domestic (Anaerobic digester for sludge)	Number
MCF – Treated Domestic (Anaerobic reactor)	Number
MCF – Treated Domestic (Anaerobic shallow lagoon)	Number
MCF – Treated Domestic (Anaerobic deep lagoon)	Number

Appendix B – Country Methodologies: United States

Buildings and Stationary Energy Sector

This section details the calculation approaches and data sources for producing community-level activity data and emission factors for the buildings and stationary energy sector. For the United States, the data estimation methodologies cover the following subsectors, initially for the year 2015:

Table B1: Methodology coverage for the building and stationary energy sector in the United States

Buildings and Stationary Energy Sector	
Residential buildings	Included
Commercial buildings	Included
Municipal buildings	Not Estimated Separately – Included in Commercial
Industry	Included
Agriculture, forestry and fisheries	Included
Fugitive emissions	Not Currently Estimated
Energy Generation	Not Currently Estimated

Residential Buildings

Subsector Overview

The residential buildings subsector encompasses all GHG emitting activities from energy use in households,[3] including heating, cooling, cooking, and lighting. The two primary categories of GHG emitting activities within the subsector are: scope 1 emissions from fuel combustion associated with residential buildings within the community boundary and scope 2 emissions from consumption of grid-supplied electricity, which may be generated outside the community boundary.

Inclusions:

For the United States, based on data availability and occurrence in-country, estimates for the following activity data points were produced:

- **Natural gas**, **distillate fuel oil**, and **kerosene** consumption by households, based on annual fuel sales to residential customers in each U.S. state.
- **Grid-supplied electricity** consumption by households, based on annual electricity sales to residential customers in each U.S. state.

Exclusions:

Due to lack of data availability or occurrence in-country, estimates for the following activity data points were not produced:

- **Off-highway motor gasoline** consumption, e.g. for use in lawn and gardening equipment
- **District heating, cooling,** or other non-electricity grid-supplied energy

Activity Data Coverage:

Table B2 outlines specific data points and energy sources covered by the methodology.

Table B2. Activity data coverage

Fuels/Energy Source	Definition	Units	Scope
Natural Gas	All natural gas consumption within community boundary for a single year for all households.	MMcf	Scope 1
Distillate Fuel Oil	All distillate fuel oil consumption within community boundary for a single year for all households.	thousand gallons	
Kerosene	All kerosene consumption within community boundary for a single year for all households.		
Grid Electricity	All grid-supplied electricity consumption within community boundary for a single year for all households	MWh	Scope 2

Calculation Methodologies:

Scope 1: Natural Gas

Methodology Notes

Residential building natural gas consumption is calculated using U.S. state-level data of natural gas sales to residential customers from the U.S. Energy Information Administration (EIA, 2017a). These initial input data are allocated to communities based on:

- the **proportion of households (by type)** in the community relative to state totals, and
- a computed **weighted average household intensity** for the community relative to the state.

Total counts of households, by housing type, are sourced from the U.S. Census Bureau / American Community Survey's *Total Housing Units* estimates, presented at census place level.[4] In addition, average annual natural gas consumption estimates (in MMBTU/household) for discrete housing categories are derived from the EIA Residential Energy Consumption Survey (RECS) (EIA, 2018). These data are combined to calculate **weighted average household intensities** that consider the relative per-unit average consumption of five broad housing types – single-family attached, single-family detached, apartments in 2-4 unit buildings, apartments in 5 or more unit buildings, and mobile homes –within different Census regions. Weighted averages are calculated for all communities relative to their state average. This is done so that estimates are reflective of the housing context within individual communities, avoiding a uniform per-household intensity across all communities in a given state and making the data more useful for comparison. The below equation represents the calculation method utilized to estimate household natural gas consumption.

Equation 1

$$\text{Community-scale household consumption} = \text{aggregate state sales}_{\text{residential}} \times \left(\frac{\text{total households}_{\text{community}}}{\text{total households}_{\text{state}}}\right) \times \left(\frac{\text{weighted avg. household intensity}_{\text{community}}}{\mathit{weighted}\ \text{avg. household intensity}_{\text{state}}}\right)$$

Table B3. Equation 1 Data Elements

Data element	Description	Source	Units
Community-scale household consumption	All natural gas consumption within community boundary for a single year for all households	Calculated	MMcf
Aggregate state sales	Amount of fuel distributed to residential customers within entire state	(EIA, 2017a)	MMcf
$total\ households_{community}$	Estimated number of households within the community	Computed value; (U.S. Census Bureau, 2015)	households
$total\ households_{state}$	Estimated number of households within the state.	(U.S. Census Bureau, 2015)	households
$weighted\ avg.\ household\ intensity_{community}$	Weighted average annual household natural gas consumption for the community	Computed value; (U.S. Census Bureau, 2015); (EIA, 2018)	MMBTU/ household
$weighted\ avg.\ household\ intensity_{state}$	Weighted average annual household natural gas consumption for the state	Computed value; (U.S. Census Bureau, 2015); (EIA, 2018)	MMBTU/ household

Methodology Assumptions and Potential Improvement

General assumptions and limitations

- Number of households, by housing type, is proportionally related to the amount of natural gas consumed within a region.
- Average energy intensities by housing type (single family, apartments in 2-4 unit buildings, etc.) remain consistent within a given region and are an appropriate weighting factor in determining consumption patterns from one community to the next.
- Within a given state and for a given housing type, factors of climate and individual housing infrastructure that may otherwise impact relative fuel consumption (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) do not vary significantly from one community to the next.

- Within a given state and for a given housing type, average household size—both in terms of square footage and number of household members—does not vary significantly from one community to the next.
- EIA state totals are assumed to encompass all household natural gas sales within a state.

Temporal assumptions and limitations

- RECS-derived average consumption figures by household type, from 2015 survey data, serve as a viable proxy for average consumption in subsequent years
- All natural gas sold to households is consumed within the year it was delivered

Potential Improvement

- As stated above, factors of climate and variation in residential building infrastructure are not taken into consideration in the current methodology. While this has simplified the initial calculation method, future iterations of the methodology will aim to incorporate factors such as heating degree days and housing infrastructure in order to add more meaningful spatial resolution to the estimates.
- Similarly, while the current approach assumes that various housing types have the same average consumption from one community to the next, there are other factors such as average income and family size that may have significant impacts on consumption. As a result, the average single-family household in one community may consume significantly higher amounts of energy in a year than that of another community in the same state. Further research is needed to determine a feasible method for accounting for such discrepancies.

Scope 1: Distillate Fuel Oil

Methodology Notes

Household distillate fuel oil[5] consumption is calculated using U.S. state-level distillate fuel oil sales data to residential customers from the U.S. Energy Information Administration (EIA, 2017b). These initial input data are allocated to communities based on:

- the **proportion of households (by type)** in the community relative to state totals, and
- a computed **weighted average household intensity** for the community relative to the state.

Total counts of households, by housing type, are sourced from the U.S. Census Bureau / American Community Survey's *Total Housing Units* estimates, presented at census place level. In addition, average annual fuel oil consumption estimates (in MMBTU/household) for discrete housing categories are derived from the EIA Residential Energy Consumption Survey (RECS) (EIA, 2018). These data are combined to calculate **weighted average household intensities** that consider the relative per-unit average consumption of five broad housing types – single-family attached, single-family detached, apartments in 2-4 unit buildings, apartments in 5 or more unit buildings, and mobile homes –within different Census regions. Weighted averages are calculated for all communities relative to their state average. This is done so that estimates are reflective of the housing context within individual communities, avoiding a uniform per-household intensity across all communities in a given state and making the data more useful for comparison. The below equation represents the calculation method utilized to estimate household distillate fuel oil consumption.

Equation 2

$$\text{Community-scale household consumption} = \text{aggregate state sales}_{\text{residential}} \times \left(\frac{\text{total households}_{\text{community}}}{\text{total households}_{\text{state}}}\right) \times \left(\frac{\text{weighted avg. household intensity}_{\text{community}}}{\textit{weighted}\ \text{avg. household intensity}_{\text{state}}}\right)$$

Table B4. Equation 2 Data Elements

Data element	Description	Source	Units
Community-scale household consumption	All distillate fuel oil consumption within community boundary for a single year for all households.	Calculated	thousand gallons
Aggregate state sales	Amount of fuel distributed to residential customers within entire state	(EIA, 2017b)	thousand gallons
$total\ households_{community}$	Estimated number of households within the community	Computed value; (U.S. Census Bureau, 2015)	households
$total\ households_{state}$	Estimated number of households within the state	(U.S. Census Bureau, 2015)	households
$weighted\ avg.\ household\ intensity_{community}$	Weighted average annual household fuel oil consumption for the community	Computed value; (U.S. Census Bureau, 2015); (EIA, 2018)	MMBTU/ household
$weighted\ avg.\ household\ intensity_{state}$	Weighted average annual household fuel oil consumption for the state	Computed value; (U.S. Census Bureau, 2015); (EIA, 2018)	MMBTU/ household

Methodology Assumptions and Potential Improvement

General assumptions

- Number of households, by housing type, is proportionally related to the amount of fuel oil consumed within a region.
- Average energy intensities by housing type (single family, apartments in 2-4 unit buildings, etc.) remain consistent within a given region and are an appropriate weighting factor in determining consumption patterns from one community to the next.
- Within a given state, factors of climate and individual housing infrastructure that may otherwise impact relative fuel consumption (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) do not vary significantly from one community to the next.

- Within a given state and for a given housing type, average household size—both in terms of square footage and number of household members—does not vary significantly from one community to the next.
- EIA state totals are assumed to encompass all fuel oil sales within a state.
- The *fuel oil* category from the RECS average consumption figures aligns definitionally with the *distillate fuel oil* category from the EIA sales data.

Temporal assumptions

- RECS-derived average consumption figures by household type, from 2015 survey data, serve as a viable proxy for average consumption in subsequent years
- All distillate fuel oil sold to households is consumed within the year it was delivered

Potential Improvement

- As stated above, factors of climate and nuances in residential building infrastructure are not taken into consideration in the current methodology. While this has simplified the initial calculation method, future iterations of the methodology will aim to incorporate factors such as heating degree days and housing infrastructure in order to add more meaningful spatial resolution to the estimates.
- Similarly, while the current approach assumes that various housing types have the same average consumption from one community to the next, there are other factors such as average income and family size that may have significant impacts on consumption. As a result, the average single-family household in one community may consume significantly higher amounts of energy in a year than that of another community in the same state. Further research is needed to determine a feasible method for accounting for such discrepancies.

Scope 1: Kerosene

Methodology Notes

Household kerosene[6] consumption is calculated using U.S. state-level kerosene sales data to residential customers from the U.S. Energy Information Administration (EIA, 2017c). These sales data are allocated to the community based on a computed ratio representing the proportion of households in the community compared to state totals.

Total counts of households, by housing type, are sourced from the U.S. Census Bureau / American Community Survey's *Total Housing Units* estimates, presented at census place level. Average household intensity weights were not calculated for kerosene consumption, as average kerosene consumption intensities do not vary meaningfully across different household types within the RECS data used. The below equation represents the calculation method utilized to estimate household kerosene consumption.

Equation 3

$$\text{Community-scale household consumption} = \text{aggregate state sales}_{\text{residential}} \times \left(\frac{\text{total single family households}_{\text{community}}}{\text{total single family households}_{\text{state}}}\right)$$

Table B5. Equation 3 Data Elements

Data element	Description	Source	Units
Community-scale household consumption	All kerosene consumption within community boundary for a single year for all households	Calculated	thousand gallons
Aggregate state sales	Amount of fuel distributed to residential customers within entire state	(EIA, 2017c)	thousand gallons
$total\ single\ family\ households_{community}$	Estimated number of single family households within the community	Computed value; (U.S. Census Bureau, 2015)	households
$total\ single\ family\ households_{state}$	Estimated number of single family households within the state	(U.S. Census Bureau, 2015)	households

Methodology Assumptions and Potential Improvement

General assumptions

- Number of households, by housing type, is proportionally related to the amount of kerosene consumed within a region.
- Within a given state, factors of climate and individual housing infrastructure that may otherwise impact relative fuel consumption (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) do not vary significantly from one community to the next.
- Within a given state and for a given housing type, average household size—both in terms of square footage and number of household members—does not vary significantly from one community to the next.
- EIA state totals are assumed to encompass kerosene sales within a state.

Temporal assumptions

- All kerosene delivered to households is consumed within the year it was delivered

Potential Improvement

- As stated above, factors of climate and nuances in residential building infrastructure are not taken into consideration in the current methodology. While this has simplified the initial calculation method, future iterations of the methodology will aim to incorporate factors such as heating degree days and housing infrastructure in order to add more meaningful spatial resolution to the estimates.
- Similarly, while the current approach assumes that various housing types have the same average consumption from one community to the next, there are other factors such as average income and family size that may have significant impacts on consumption. As a result, the average single-family household in one community may consume significantly higher amounts of energy in a year than that of another community in the same state. Further research is needed to determine a feasible method for accounting for such discrepancies.

Scope 2: Electricity

Methodology Notes

Residential building electricity consumption is calculated using U.S. state-level electricity sales data to residential customers from the U.S. Energy Information Administration (EIA, 2017d). State-level sales data for the residential sector is calculated as the sum of all sales (in MWh), for EIA 861 parts A and C only[7], for the residential end-use category. These initial input data are allocated to communities based on:

- the **proportion of households (by type)** in the community relative to state totals, and
- a computed **weighted average household intensity** for the community relative to the state.

Total counts of households, by housing type, are sourced from the U.S. Census Bureau / American Community Survey's *Total Housing Units* estimates, presented at census place level. In addition, average annual electricity consumption estimates (in MMBTU/household) for discrete housing categories are derived from the EIA Residential Energy Consumption Survey (RECS) (EIA, 2018). These data are combined to calculate **weighted average household intensities** that consider the relative per-unit average consumption of five broad housing types – single-family attached, single-family detached, apartments in 2-4 unit buildings, apartments in 5 or more unit buildings, and mobile homes – within different Census regions. Weighted averages are calculated for all communities relative to their state average. This is done so that estimates are reflective of the housing context within individual communities, avoiding a uniform per-household intensity across all communities in a given state and making the data more useful for comparison. The below equation represents the calculation method utilized to estimate household electricity consumption.

Equation 4

$$\text{Community-scale household consumption} = \text{aggregate state sales}_{\text{residential}} \times \left(\frac{\text{total households}_{\text{community}}}{\text{total households}_{\text{state}}}\right) \times \left(\frac{\text{weighted avg. household intensity}_{\text{community}}}{\textit{weighted}\text{ avg. household intensity}_{\text{state}}}\right)$$

Table B6. Equation 4 Data Elements

Data element	Description	Source	Units
Community-scale household consumption	All electricity consumption within community boundary for a single year for all household buildings	Calculated	MWh
Aggregate state sales	Amount of electricity distributed to residential customers within entire state	(EIA, 2017d)	MWh
$total\ households_{community}$	Estimated number of households within the community	Computed value; (U.S. Census Bureau, 2015)	households

$total\ households_{state}$	Estimated number of households within the state	(U.S. Census Bureau, 2015)	households
$weighted\ avg.\ household\ intensity_{community}$	Weighted average annual household electricity consumption for the community	Computed value; (U.S. Census Bureau, 2015); (EIA, 2018)	MMBTU/ household
$weighted\ avg.\ household\ intensity_{state}$	Weighted average annual household electricity consumption for the state	Computed value; (U.S. Census Bureau, 2015); (EIA, 2018)	MMBTU/ household

Methodology Assumptions and Potential Improvement

General assumptions

- Number of households, by housing type, is proportionally related to the amount of electricity consumed within a region.
- Average energy intensities by housing type (single family, apartments in 2-4 unit buildings, etc.) remain consistent within a given region and are an appropriate weighting factor in determining consumption patterns from one community to the next.
- Within a given state, factors of climate and individual housing infrastructure that may otherwise impact relative fuel consumption (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) do not vary significantly from one community to the next.
- Within a given state and for a given housing type, average household size—both in terms of square footage and number of household members—does not vary significantly from one community to the next.
- EIA state totals are assumed to encompass all electricity sales within a state.

Temporal assumptions

- RECS-derived average consumption figures by household type, from 2015 survey data, serve as a viable proxy for average consumption in subsequent years

Limitations

- Consumption data does not include electricity from on-site generation

Potential Improvement

- As stated above, factors of climate and nuances in residential building infrastructure are not taken into consideration in the current methodology. While this has simplified the initial calculation method, future iterations of the methodology will aim to incorporate factors such as heating degree days and housing infrastructure in order to add more meaningful spatial resolution to the estimates.
- Similarly, while the current approach assumes that various housing types have the same average consumption from one community to the next, there are other factors such as average income and family size that may have significant impacts on consumption. As a result, the average

single-family household in one community may consume significantly higher amounts of energy in a year than that of another community in the same state. Further research is needed to determine a feasible method for accounting for such discrepancies.

Table B7. Emission Factors:

Fuel Type	kg CO2 per scf	g CH4 per scf	g N2O per scf	Source
Natural Gas	0.05444	0.00103	0.00010	(EPA, 2015)

Fuel Type	kg CO2 per gallon	g CH4 per gallon	g N2O per gallon	Source
Distillate Fuel Oil[8]	10.45	0.42	0.08	(EPA, 2015)
Kerosene	10.15	0.41	0.08	(EPA, 2015)

Fuel Type	
Grid Electricity	See Appendix E

Sources: EPA 2015 (natural gas, distillate fuel oil); EPA 2018 (grid electricity)

References:

EIA. (2018). Residential Energy Consumption Survey (RECS) 2015 Survey Data. Consumption & Expenditures (C&E) Tables. Tables CE2.1-5. Release date: 5/31/18. Retrieved from: https://www.eia.gov/consumption/residential/data/2015/

Provides average consumption intensity figures used to develop regional weights based on the number of various housing types (e.g. single family, multi-unit).

EIA. (2017a). Natural Gas Consumption by End Use. Release date: 12/29/2017. Retrieved from: https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm

Provides state-level natural gas sales totals by end-use category, which are disaggregated to the community-scale.

EIA. (2017b). Sales of Distillate Fuel Oil by End Use. Release date: 12/19/2017. Retrieved from: https://www.eia.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm

Provides state-level fuel oil sales totals by end-use category, which are disaggregated to the community scale.

EIA. (2017c). Sales of Kerosene by End Use. Release date: 12/19/2017. Retrieved from: https://www.eia.gov/dnav/pet/pet_cons_821ker_dcu_nus_a.htm

Provides state-level kerosene sales totals by end-use category, which are disaggregated to the community scale.

EIA. (2017d). Form EIA-861 detailed data files. Sales to Ultimate Customers. Release date: 11/6/17. Retrieved from: https://www.eia.gov/electricity/data/eia861/

Provides state-level electricity sales totals by end-use category, which are disaggregated to the community-scale.

EPA. (2015). Emission Factors for Greenhouse Gas Inventories. EPA Center for Corporate Climate Leadership. Last modified: 11/19/15. Retrieved from: https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

Provides U.S.-specific emission factors for the combustion of fuels included in the methodology.

EPA. (2018). Emissions & Generation Resource Integrated Database (eGRID). eGRID 2016. Released: 2/15/2018. Retrieved from: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Provides U.S. grid region-specific emission factors for electricity consumption.

U.S. Census Bureau. (2010). 2010 ZCTA to Place Relationship File. Retrieved from: https://www.census.gov/geo/maps-data/data/zcta_rel_download.html

U.S. Census Bureau. (2015). American Community Survey 1-Year Estimates – Selected Housing Characteristics. Retrieved from: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

Provides estimates of the number of houses, by housing type (e.g. single family, multi-unit), at the ZIP-code level.

Commercial Buildings

Subsector Summary:

The commercial buildings subsector encompasses all GHG emitting activities from energy use in commercial buildings, including heating, cooling, and lighting. The two primary categories of GHG emitting activities within the subsector are: scope 1 emissions from fuel combustion associated with commercial buildings within the community boundary and scope 2 emissions from consumption of grid-supplied electricity.

Inclusions:

For the United States, based on data availability and occurrence in-country, estimates for the following activity data points were produced:

- **Natural gas** and **distillate fuel oil** consumption by commercial buildings, based on annual fuel sales to commercial customers in each U.S. state
- **Electricity** consumption by commercial buildings, based on annual electricity sales to commercial customers in each U.S. state

Exclusions:

Due to lack of data availability or occurrence in-country, estimates for the following activity data points were not produced:

- **Off-highway motor gasoline** consumption, e.g. for use in landscaping equipment
- **District heating, cooling,** or other non-electricity grid-supplied energy

Activity Data Coverage:

The specific data points and energy sources covered by the methodology are outlined in Table B8.

Table B8. Activity Data Coverage

Fuels/Energy Source	Definition	Units	Scope
Natural Gas	Natural gas consumption within community boundary for a single year for all commercial buildings	MMcf	Scope 1
Distillate Fuel Oil	Distillate fuel oil consumption within community boundary for a single year for all commercial buildings	thousand gallons	
Grid Electricity	Grid-supplied electricity consumption within community boundary for a single year for all commercial buildings	MWh	Scope 2

Note: the primary input data used in this methodology from EIA lists municipalities as a part of the aggregate commercial end-use sector. Supplemental information on the relative share of total commercial energy sales comprised by municipalities versus other end-use categories is not provided. Given this, consumption from municipal buildings is currently embedded within the commercial buildings category by default and not estimated as its own subsector. More information on this limitation can be found in the Commercial Buildings section of this technical note.

Calculation Methodologies:

Scope 1: Natural Gas

Methodology Notes

Commercial sector natural gas consumption is calculated using state-level natural gas sales data to commercial customers from the U.S. Energy Information Administration (EIA, 2017a). These sales data are combined with computed ratios representing:

1) the **proportion of employees** in the community relative to the state, and
2) a computed **weighted average per-employee energy intensity** for the community relative to the state.

Census data are used to estimate the number of employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place[9] mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code population residing within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that population serves as a viable proxy for the distribution of commercial buildings. It is important to note that some ZIP codes containing commercial establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate in order to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into commercial sector and non-commercial sector totals based on NAICS code. Estimates corresponding to NAICS codes falling outside of the commercial sector, such as agriculture, forestry, and fishing sectors, are filtered out and retained for other sub-sector estimates (see accompanying appendices). In lieu of commercial building floor space information, commercial sector employee totals are assumed to be a viable disaggregation factor for EIA commercial end-use sector natural gas sales. EIA guidance on the exact sub-categories encompassed by the commercial end-use sector is limited, however reasonable assumptions are made regarding the general alignment of this end-use sector and the NAICS codes used for the commercial sector employee estimates. Figure C1 in Appendix C provides a simplified visual representation of how these data elements are mapped.

Finally, commercial building natural gas consumption is allocated to communities not simply based on number of estimated employees, but by a **weighted average per-employee energy intensity** which takes into consideration the relative per-employee natural gas intensity for commercial establishments of different sizes. Weighted average per-employee intensities are calculated at the state and community level based on nine establishment size ranges matching those from the Census *Business Patterns* data described above (e.g. 1-4 employees, 5-9 employees, etc.). Average annual natural gas consumption estimates (in MMBTU/employee) for each of the nine establishment size ranges, derived from the EIA Commercial Building Energy Consumption Survey (CBECS) (EIA, 2018), are matched to the number of employees corresponding to each establishment range to generate weighted average per-employee energy intensity figures. This is done so that estimates are more reflective of the building context within individual communities, avoiding a uniform per-employee intensity across all communities and making the data more useful for comparison. The below equation represents the calculation method utilized to estimate commercial sector natural gas consumption.

Equation 5

$$\text{Community-scale commercial consumption} = \text{aggregate state sales}_{\text{commercial}} \times \left(\frac{\text{sector employees}_{\text{community}}}{\text{sector employees}_{\text{state}}}\right) \times \left(\frac{\text{avg. employee intensity}_{\text{community}}}{\text{avg. employee intensity}_{\text{state}}}\right)$$

Table B9. *Equation 5 Data Elements*

Data element	Description	Source	Units
Community-scale commercial consumption	Natural gas consumption within community boundary for a single year for all commercial buildings	Calculated	MMcf
Aggregate state sales	Amount of fuel distributed to commercial customers within entire state	(EIA, 2017a)	MMcf
commercial $\text{employees}_{\text{community}}$	Estimated number of commercial sector employees for the community	Computed value; (U.S. Census Bureau, 2017)	employees
commercial $\text{employees}_{\text{state}}$	Estimated number of commercial sector employees within the state	Computed value; (U.S. Census Bureau, 2017)	employees
avg. employee $\text{intensity}_{\text{community}}$	Weighted average annual natural gas consumption per employee for the community.	Computed value; (U.S. Census Bureau, 2017); (EIA, 2015)	ccf/employee

Data element	Description	Source	Units
avg. employee intensity$_{state}$	Weighted average annual natural gas consumption per employee within state.	Computed value; (U.S. Census Bureau, 2017); (EIA, 2015)	ccf/employee

Methodology Assumptions and Potential Improvement

General assumptions

- Number of commercial sector employees is proportionally related to the amount of natural gas consumed.
- NAICS classification codes used to produce commercial sector employee estimates align with what the EIA defines as the commercial end-use sector in its energy sales data
- Energy intensity within the commercial sector does not vary significantly from one sub-category to the next (e.g. wholesale trade, retail trade, banking and finance, education, etc.)

Spatial assumptions

- Within a state boundary, factors of climate and individual building infrastructure that may otherwise impact relative fuel consumption (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) are static.
- The distribution of commercial sector natural gas consumption within a state is proportionally related to the distribution of commercial establishments and employees.
- The distribution of commercial establishments and employees within a ZIP code territory is proportionally related to population distribution.

Temporal assumptions

- CBECS-derived average per-employee consumption figures by establishment size, from 2012 survey data, serve as a viable proxy for average per-employee consumption in subsequent years.
- All natural gas sold to commercial customers is consumed within the year it was delivered

Potential Improvement

As stated above, an underlying assumption of the current calculation methodology is that the factors of climate and nuances in building infrastructure and discrete fuel needs (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) are constant within an entire state boundary. This assumption was made to simplify the initial calculation method, however within a given state there may be significant differences in weather, building efficiency, cooking equipment, heating and cooling technology (and the types of fuel sources associated with them) at the sub-state scale that impact energy consumption. Future iterations of the methodology will aim to incorporate factors such as heating degree days, cooling degree days, and building infrastructure to add more meaningful spatial resolution to the estimates.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as floor space (e.g. in m^2) (Kelly 2011). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on floor space, by contrast, is typically proprietary in the United States and not an open data source.

Finally, weights used in the current iteration partially take account differences in the building context of each community in terms of the size of establishments. This is done because, on average, employees in buildings with higher numbers of total employees generally have a lower per-employee intensity than those in smaller establishments, indicating a need to weight estimates accordingly. Additional weighting and calibration are necessary, however, in order to account for differences in per-employee intensities not just based on establishment sizes, but by different categories of commercial enterprises such as finance, education, and retail trade. Future iterations will incorporate these additional into final estimates.

Scope 1: Distillate Fuel Oil

Methodology Notes

Commercial sector distillate fuel oil consumption is calculated using state-level distillate fuel oil sales data to commercial customers from the U.S. Energy Information Administration (EIA, 2017a). These sales data are combined with computed ratios representing:

1) the **proportion of employees** in the community relative to the state, and
2) a computed **weighted average per-employee energy intensity** for the community relative to the state.

Census data are used to estimate the number of employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code population residing within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that population serves as a viable proxy for the distribution of commercial buildings. It is important to note that some ZIP codes containing commercial establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate in order to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into commercial sector and non-commercial sector totals based on NAICS code. Estimates corresponding to NAICS codes falling outside of the commercial sector, such as agriculture, forestry, and fishing sectors, are filtered out and retained for other sub-sector estimates (see accompanying appendices). In lieu of commercial building floor space information, commercial sector employee totals are assumed to be a viable disaggregation factor for EIA commercial end-use sector distillate fuel oil sales. EIA guidance on the exact sub-categories encompassed by the commercial end-use sector is limited, however reasonable assumptions are made regarding the general alignment of this end-use sector and the NAICS codes used for the commercial sector employee estimates. Figure C1 in Appendix C provides a simplified visual representation of how these data elements are mapped.

Finally, commercial building distillate fuel oil consumption is allocated to communities not simply based on number of estimated employees, but by a **weighted average per-employee energy intensity** which takes into consideration the relative per-employee fuel oil intensity for commercial establishments of different sizes. Weighted average per-employee intensities are calculated at the state and community level based on nine establishment size ranges matching those from the Census *Business Patterns* data described above (e.g. 1-4 employees, 5-9 employees, etc.). Average annual fuel oil consumption estimates (in MMBTU/employee) for each of the nine establishment size ranges, derived from the EIA Commercial Building Energy Consumption Survey (CBECS) (EIA, 2018), are matched to the number of employees corresponding to each establishment range to generate weighted average per-employee energy intensity figures. This is done so that estimates are more reflective of the building context within individual communities, avoiding a uniform per-employee intensity across all communities and making the data more useful for comparison. The below equation represents the calculation method utilized to estimate commercial sector distillate fuel oil consumption.

Equation 6

$$\text{Community-scale commercial consumption} = \text{aggregate state sales}_{\text{commercial}} \times \left(\frac{\text{sector employees}_{\text{community}}}{\text{sector employees}_{\text{state}}}\right) \times \left(\frac{\text{avg. employee intensity}_{\text{community}}}{\text{avg. employee intensity}_{\text{state}}}\right)$$

Table B10. Equation 6 Data Elements

Data element	Description	Source	Units
Community-scale commercial consumption	Distillate fuel oil consumption within community boundary for a single year for all commercial buildings	Calculated	MMBTU
Aggregate state sales	Amount of fuel distributed to commercial customers within entire state	(EIA, 2017b)	MMBTU
commercial employees$_{\text{community}}$	Estimated number of commercial sector employees for the community	Computed value; (U.S. Census Bureau, 2017)	employees
commercial employees$_{\text{state}}$	Estimated number of commercial sector employees within the state	Computed value; (U.S. Census Bureau, 2017)	employees

Data element	Description	Source	Units
avg. employee intensity$_{community}$	Weighted average annual fuel oil consumption per employee for the community.	Computed value; (U.S. Census Bureau, 2017); (EIA, 2015)	MMBTU/employee
avg. employee intensity$_{state}$	Weighted average annual fuel oil consumption per employee within state.	Computed value; (U.S. Census Bureau, 2017); (EIA, 2015)	MMBTU/employee

Methodology Assumptions and Potential Improvement

General assumptions

- NAICS classification codes used to produce commercial sector employee estimates align with what the EIA defines as the commercial end-use sector in its energy sales data
- Energy intensity within the commercial sector does not vary significantly from one sub-category to the next (e.g. wholesale trade, retail trade, banking and finance, education, etc.)
- The *fuel oil* category from the CBECS average consumption figures aligns definitionally with the *distillate fuel oil* category from the EIA sales data

Spatial assumptions

- Within a state boundary, factors of climate and individual building infrastructure that may otherwise impact relative fuel consumption (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) are static.
- The distribution of commercial sector distillate fuel oil consumption within a state is proportionally related to the distribution of commercial sector establishments and employees.
- The distribution of commercial establishments and employees within a ZIP code territory is proportionally related to population distribution.

Temporal assumptions

- CBECS-derived average per-employee consumption figures by establishment size, from 2012 survey data, serve as a viable proxy for average per-employee consumption in subsequent years.
- All distillate fuel oil sold to commercial customers is consumed within the year it was delivered

Potential Improvement

As stated above, an underlying assumption of the current calculation methodology is that the factors of climate and nuances in building infrastructure and discrete fuel needs (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) are static across an entire state boundary. This assumption was made to simplify the initial calculation method, however within a given state there may be significant differences in weather, building efficiency, cooking equipment, heating and cooling technology (and the types of fuel sources associated with them) at the sub-state scale that impact energy consumption. Future iterations of the methodology will aim to incorporate factors such as heating degree days, cooling degree days, and building infrastructure to add more meaningful spatial resolution to the estimates.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as floor space (e.g. in m^2). More testing and research are needed to determine whether floor space at the community scale would result in more accurate estimates. However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on floor space, by contrast, is typically proprietary in the United States and not an open data source.

Finally, weights used in the current iteration partially take account differences in the building context of each community in terms of the size of establishments. This is done because, on average, employees in buildings with higher numbers of total employees generally have a lower per-employee intensity than those in smaller establishments, indicating a need to weight estimates accordingly. Additional weighting and calibration are necessary, however, in order to account for differences in per-employee intensities not just based on establishment sizes, but by different categories of commercial enterprises such as finance, education, and retail trade. Future iterations will incorporate these additional into final estimates.

Scope 2: Electricity

Methodology Notes

Commercial sector electricity consumption is calculated using state-level electricity sales data to commercial customers from the U.S. Energy Information Administration (EIA, 2017c). These sales data are combined with computed ratios representing:

1) the **proportion of employees** in the community relative to the state, and
2) a computed **weighted average per-employee energy intensity** for the community relative to the state.

State-level sales data for the commercial sector is calculated as the sum of all sales (in MWh), for EIA 861 parts A and C only, for the commercial end-use category.

Census data are used to estimate the number of employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code population residing within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that population serves as a viable proxy for the distribution of commercial buildings. It is important to note that some ZIP codes containing commercial establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate in order to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into commercial sector and non-commercial sector totals based on NAICS code. Estimates corresponding to NAICS codes falling outside of the commercial sector, such as agriculture, forestry, and fishing sectors, are filtered out and retained for other sub-sector estimates (see accompanying appendices). In lieu of commercial building floor space information, commercial sector employee totals are assumed to be a viable disaggregation factor for EIA commercial end-use sector distillate electricity sales. EIA guidance on the exact sub-categories encompassed by the commercial end-use sector is limited, however reasonable assumptions are made regarding the general alignment of this end-use sector and the NAICS codes used for the commercial sector employee estimates. Figure C1 in Appendix C provides a simplified visual representation of how these data elements are mapped.

Finally, commercial building distillate electricity consumption is allocated to communities not simply based on number of estimated employees, but by a **weighted average per-employee energy intensity** which takes into consideration the relative per-employee electricity intensity for commercial establishments of different sizes. Weighted average per-employee intensities are calculated at the state and community level based on nine establishment size ranges matching those from the Census *Business Patterns* data described above (e.g. 1-4 employees, 5-9 employees, etc.). Average annual electricity consumption estimates (in MMBTU/employee) for each of the nine establishment size ranges, derived from the EIA Commercial Building Energy Consumption Survey (CBECS) (EIA, 2018), are matched to the number of employees corresponding to each establishment range to generate weighted average per-employee energy intensity figures. This is done so that estimates are more reflective of the building context within individual communities, avoiding a uniform per-employee intensity across all communities and making the data more useful for comparison. The below equation represents the calculation method utilized to estimate commercial sector electricity consumption.

Equation 7

$$\text{Community-scale commercial consumption} = \text{aggregate state sales}_{\text{commercial}} \times \left(\frac{\text{sector employees}_{\text{community}}}{\text{sector employees}_{\text{state}}}\right) \times \left(\frac{\text{avg. employee intensity}_{\text{community}}}{\text{avg. employee intensity}_{\text{state}}}\right)$$

Table B*11. Equation 7 Data Elements*

Data element	Description	Source	Units
Community-scale commercial consumption	Electricity consumption within community boundary for a single year for all commercial buildings	Calculated	mwh
Aggregate state sales	Electricity sales to commercial customers within entire state	(EIA, 2017c)	mwh
commercial $\text{employees}_{\text{community}}$	Estimated number of commercial sector	Computed value; (U.S.	employees

	employees for the community	Census Bureau, 2017)	
commercial $employees_{state}$	Estimated number of commercial sector employees within the state	Computed value; (U.S. Census Bureau, 2017)	employees
avg. employee $intensity_{community}$	Weighted average annual electricity consumption per employee for the community.	Computed value; (U.S. Census Bureau, 2017); (EIA, 2015)	mwh/employee
avg. employee $intensity_{state}$	Weighted average annual electricity consumption per employee within state.	Computed value; (U.S. Census Bureau, 2017); (EIA, 2015)	mwh/employee

Methodology Assumptions and Potential Improvement

General assumptions

- NAICS classification codes used to produce commercial sector employee estimates align with what the EIA defines as the commercial end-use sector in its energy sales data
- Energy intensity within the commercial sector does not vary significantly from one sub-category to the next (e.g. wholesale trade, retail trade, banking and finance, education, etc.)

Spatial assumptions

- Within a state boundary, factors of climate and individual building infrastructure that may otherwise impact relative fuel consumption (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) are static.
- The distribution of commercial sector electricity consumption within a state is proportionally related to the distribution of commercial sector establishments and employees.
- The distribution of commercial establishments and employees within a ZIP code territory is proportionally related to population distribution.

Temporal assumptions

- CBECS-derived average per-employee consumption figures by establishment size, from 2012 survey data, serve as a viable proxy for average per-employee consumption in subsequent years.

Limitations

- Consumption data does not include electricity from on-site generation

Potential Improvement

As stated above, an underlying assumption of the current calculation methodology is that the factors of climate and nuances in building infrastructure and discrete fuel needs (e.g. relative mix of natural gas, fuel oil, or electricity used for heating) are static across an entire state boundary. This assumption was made to simplify the initial calculation method, however within a given state there may be significant differences in weather, building efficiency, cooking equipment, heating and cooling technology (and the types of fuel sources associated with them) at the sub-state scale that impact energy consumption. Future iterations of the methodology will aim to incorporate factors such as heating degree days, cooling degree days, and building infrastructure to add more meaningful spatial resolution to the estimates.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as floor space (e.g. in m^2) – including the NREL State and Local Planning for Energy (SLOPE) platform (NREL 2020). More testing and research are needed to determine whether floor space at the community scale would result in more accurate estimates. However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on floor space, by contrast, is typically proprietary in the United States and not an open data source.

Finally, weights used in the current iteration partially take account differences in the building context of each community in terms of the size of establishments. This is done because, on average, employees in buildings with higher numbers of total employees generally have a lower per-employee intensity than those in smaller establishments, indicating a need to weight estimates accordingly. Additional weighting and calibration are necessary, however, in order to account for differences in per-employee intensities not just based on establishment sizes, but by different categories of commercial enterprises such as finance, education, and retail trade. Future iterations will incorporate these additional into final estimates.

Table B12. Emission Factors

Fuel Type	kg CO2 per scf	g CH4 per scf	g N2O per scf	Source
Natural Gas	0.05444	0.00103	0.00010	(EPA, 2015)

Fuel Type	kg CO2 per gallon	g CH4 per gallon	g N2O per gallon	Source
Distillate Fuel Oil[10]	10.45	0.42	0.08	(EPA, 2015)

Grid Electricity	See Appendix E

Sources: EPA 2015 (natural gas, distillate fuel oil); EPA 2018 (grid electricity)

References:

EIA. (2015). 2012 Commercial Building Energy Consumption Survey (CBECS). 2012 CBECS Microdata. Release date: 6/2015. Retrieved from: https://www.eia.gov/consumption/commercial/data/2012/index.php?view=microdata

Used to develop regional weights based on the number of employees in various establishment size classes (e.g. 1-4 employees, 50-100 employees, etc.)

EIA. (2017a). Natural Gas Consumption by End Use. Release date: 12/29/2017. Retrieved from: https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm

Provides state-level natural gas sales totals by end-use category, which are disaggregated to the community-scale.

EIA. (2017b). Sales of Distillate Fuel Oil by End Use. Release date: 12/19/2017. Retrieved from: https://www.eia.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm

Provides state-level fuel oil sales totals by end-use category, which are disaggregated to the community scale.

EIA. (2017c). Form EIA-861 detailed data files. Sales to Ultimate Customers. Release date: 11/6/17. Retrieved from: https://www.eia.gov/electricity/data/eia861/

Provides state-level electricity sales totals by end-use category, which are disaggregated to the community-scale.

EPA. (2015). Emission Factors for Greenhouse Gas Inventories. EPA Center for Corporate Climate Leadership. Last modified: 11/19/15. Retrieved from: https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

Provides U.S.-specific emission factors for the combustion of fuels included in the methodology.

EPA. (2018). Emissions & Generation Resource Integrated Database (eGRID). eGRID 2016. Released: 2/15/2018. Retrieved from: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Provides U.S. grid region-specific emission factors for electricity consumption.

Kelly S. 2011. “Do homes that are more energy efficient consume less energy?: A structural equation model of the English residential sector,” *Energy*, vol. 36, no. 9, pp. 5610–5620, September 2011.

NREL (National Renewable Energy Laboratory). 2020. (Database). *State and Local Planning for Energy*. https://gds.nrel.gov/slope

U.S. Census Bureau. (2017). CBP Datasets - 2015: Complete ZIP Code Industry Detail File; Complete ZIP Code Totals File. Released 4/20/17. Retrieved from: https://www.census.gov/data/datasets/2015/econ/cbp/2015-cbp.html

Used to estimate the number of commercial sector employees, by establishment size, at the ZIP code level.

Municipal Buildings

As of yet, a computation methodology has not been developed to estimate community scale activity data for the municipal buildings sector in the United States. This gap in data coverage stems largely from two related issues: 1) a lack of disaggregation of state-level fuel and electricity sales data released by the EIA and 2) a lack of supplementary data that could be used as a viable disaggregation factor.

Issue 1: Lack of disaggregation of state-level data

The EIA releases state-level electricity and fuel sales data (e.g. EIA 861 Sales to Ultimate Customers) that is generally disaggregated into the broad end use categories of residential, commercial, industrial, and – in the case of fuel sales data such as distillate fuel oil and kerosene – additional categories such as farm or transportation sectors. For the U.S. computation methodology, these state level aggregate totals by end-use category represent a starting point from which data are further disaggregated to smaller regional scales.

As illustrated in Table B13, EIA sales data are pre-disaggregated in a way that generally aligns with the stationary energy sub-sectors. A notable exception, however, is that "municipalities" and "public street and highway lighting," two categories that would typically fall under the separate sub-sector of municipal buildings, are included in EIA's commercial end-use category. What's more, the EIA does not provide estimates of the share of total sales made up by these various sub-categories. As a result, municipal electricity consumption remains embedded within EIA's broader commercial category without any apparent means of separating it out.

Table B13 – Subcategories of Electricity End-Use Defined by EIA

Residential End-Use Category (from EIA 861):	Commercial End-Use Category (from EIA 861):	Industrial End-Use Category (from EIA
Includes private households and apartment buildings where energy is consumed primarily for: • space heating • water heating • air conditioning • lighting • refrigeration • cooking • clothes drying	Includes nonmanufacturing business establishments such as: • hotels • motels, • restaurants • wholesale businesses • retail stores • health, social, and educational institutions • public street and highway lighting	Includes: • manufacturing • construction • mining • agriculture (irrigation), • fishing • forestry establishments

Source: Energy Information Agency. (2017) Form EIA 861 Annual Electric Power Industry Report Instructions. Sales to Ultimate Customers. Release date: 11/6/17. Retrieved from: https://www.eia.gov/electricity/data/eia861/

Issue 2: Lack of Supplementary Data to Provide Disaggregation Factor

It is sometimes the case that top-down datasets, even if not initially pre-disaggregated into the desired sub-categories, may still be disaggregated with supplementary data and information. For example, even though EIA groups industrial (e.g. manufacturing and construction) and agriculture, forestry and fishing end-users under the same broad category (see Table B13), supplementary datasets can be used to determine the relative share each sub-category would make up, on average, and apportion the total state sales accordingly. This method is used in this U.S.-specific methodology and is described in more detail in the industrial and agriculture, forestry, and fishing appendices.

At this time, similar supplementary data has not been found to serve as a disaggregation factor for EIA's commercial end use sector and establish separate totals for municipal and commercial buildings. Further research will still be needed to determine if such a method can be developed.

Industrial

Subsector Summary:

The industrial subsector encompasses all GHG emitting activities from energy use by industrial establishments, including heating, cooling, lighting, and the operation of machinery. The two primary categories of GHG emitting activities within the subsector are: scope 1 emissions from fuel combustion associated with industrial establishments within the community boundary and scope 2 emissions from consumption of grid-supplied energy.

Inclusions:

For the United States, based on data availability and occurrence in-country, estimates for the following activity data points were produced:

- **Natural gas**, **distillate fuel oil**, **residual fuel oil**, and **kerosene** consumption by industrial establishments, based on annual fuel sales to industrial customers in each U.S. state
- **Grid-supplied electricity** consumption by industrial establishments, based on annual electricity sales to industrial customers in each U.S. state

Exclusions:

Due to lack of data availability or occurrence in-country, estimates for the following activity data points were not produced:

- **Coal** consumption for on-site energy in industrial establishments
- **Off-highway motor gasoline** consumption, e.g. for use in construction, mining, and other industrial equipment
- **District heating, cooling,** or other non-electricity grid-supplied energy

The specific data points and energy sources covered by the methodology are outlined in the table below.

Table B14. Activity Data Coverage

Fuels/Energy Source	Definition	Units	Scope
Natural Gas	All natural gas consumption within community boundary for a single year for all industrial establishments	MMcf	Scope 1
Distillate Fuel Oil	All distillate fuel oil consumption within community boundary for a single year for all industrial establishments	thousand gallons	
Residual Fuel Oil	All residual fuel oil consumption within community boundary for a single year for all industrial establishments	thousand gallons	
Kerosene	All kerosene consumption within community boundary for a single year for all industrial establishments	thousand gallons	
Grid Electricity	All grid-supplied electricity consumption within community boundary for a single year for all industrial establishments	MWh	Scope 2

Note: While estimates are ultimately presented for the industrial sector in aggregate, the methodology (described in more detail below) actually results in separate estimates for three categories of industrial activity at the community scale: manufacturing, construction, and mining, quarrying, and oil and gas.

Calculation Methodologies:

Scope 1: Natural Gas

Methodology Notes

Industrial sector natural gas consumption is calculated using state-level natural gas sales data to industrial customers from the U.S. Energy Information Administration (EIA, 2017a) and supplementary Bureau of Economic Analysis data (BEA, 2014). These sales data are combined with computed ratios representing:

- the **proportion of employees** in the community relative to the state, and
- a computed **weighted average per-employee energy intensity** for the community relative to the state (done for manufacturing industry subtype only).

Various types of industry exhibit significantly different natural gas consumption patterns, however EIA sales data are available only in aggregate and not broken-out by industry subtype. To address this, supplemental data are used to estimate and pull out the share of EIA state-level sales data comprised by three broad industrial subtypes: a) manufacturing, b) construction, and c) mining, quarrying, and oil and gas. The supplemental data used, BEA's *Input-Output* data tables, provide a representation of the flow of commodities between industries, identified by North American Industry Classification System (NAICS) IDs. The tables are used to estimate the relative share of total state natural gas consumption that can be attributed to the three industry subtypes, resulting in separate totals for each at the state level.

Census data are used to estimate the number of employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code population residing within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that population serves as a viable proxy for the distribution of industrial establishments and employees. It is important to note that some ZIP codes containing industrial establishments and their associated employees may partially or completely fall outside of any census place boundary – e.g., a factory located in an unincorporated area near but outside the closest community's boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate in order to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into industrial sector and non-industrial sector totals based on NAICS code. Total industrial employee estimates are further subdivided into separate totals for the manufacturing, construction, and mining, quarrying, and oil and gas NAICS codes. Estimates corresponding to NAICS codes falling outside of the industrial sector are filtered out and retained for other sub-sector estimates (see accompanying appendices).

Industrial sector employee totals are assumed to be a viable disaggregation factor for state-level EIA industry end-use sector natural gas sales. EIA guidance on the exact sub-categories encompassed by the industry end-use sector is limited, however reasonable assumptions are made regarding the general alignment of this end-use sector and the NAICS codes used for the industrial sector employee estimates. Figure C1 in Appendix C provides a simplified visual representation of how these data elements are mapped.

For the manufacturing industrial category only, natural gas consumption is allocated to the community not simply by relative consumption patterns of industry sub-types and the number of industrial sector employees, but also but by a **weighted average per-employee energy intensity** which takes into consideration the relative per-employee natural gas intensity of establishments of different sizes. Weighted average per-employee intensities are calculated at the state and community level based on nine establishment size ranges matching those from the Census Business Patterns data described above (e.g. 1-4 employees, 5-9 employees, etc.). Average annual natural gas consumption estimates (in MMBTU/employee) for each of the nine establishment size ranges, derived from the EIA Manufacturing Energy Consumption Survey (MECS) (EIA, 2017e), are matched to the number of employees corresponding to each establishment range to generate weighted average per-employee energy intensity figures. This is done so that estimates are more reflective of the establishment size context within individual communities, avoiding a uniform per-employee intensity across all communities and making the data more useful for comparison. Similar weights were not calculated for the construction or mining, quarrying and oil and gas industrial subtypes because EIA does not have equivalent data for these categories.

The below equation represents the calculation method utilized to apportion aggregate natural gas sales for the industrial end-use sector at the state level into constituent industry subtypes (manufacturing, construction, and mining, quarrying, and oil and gas).

Equation 8

$$Aggregate\ state\ sales_{industrial\ subtype} = aggregate\ state\ sales_{industrial} \times \frac{national\ commodity\ consumption\ level_{industrial\ subtype}}{national\ commodity\ conslumption\ level_{industrial}}$$

Table B*15. Equation 8 Data Elements*

Data element	Description	Source	Units
Aggregate state sales$_{industrial\ subtype}$	Estimated amount of state level natural gas sales apportioned to industrial subtype (e.g. manufacturing, construction, mining, quarrying, and oil and gas	Calculated	MMcf
Aggregate state sales$_{industrial}$	Amount of natural gas distributed to all industrial customers within entire state	(EIA, 2017a)	MMcf
National commodity consumption level$_{industrial\ subtype}$	Value of natural gas commodity consumed at national scale for industry subtype	(BEA, 2014)	million USD
National commodity consumption level$_{industrial}$	Value of natural gas commodity consumed at national scale for all industry.	(BEA, 2014)	million USD

The below equation represents the calculation method utilized to estimate total industrial sector natural gas consumption at the community scale.

Equation 9

$$Community - scale\ industrial\ consumption = \sum_{industry\ subtype} \left(aggregate\ state\ sales_{industry\ subtype} \times \frac{total\ community\ employees_{industry\ subtype}}{total\ state\ employees_{industry\ subtype}} \times \frac{commnity\ avg.\ employee\ intensity}{state\ avg.\ employee\ intensity} \right)$$

Table B*16. Equation 9 Data Elements*

Data element	Description	Source	Units
Community-scale industrial consumption	All natural gas consumption within community boundary for a single year for all industrial establishments	Calculated	MMcf
Aggregate state sales $_{industry\ subtype}$	Estimated amount of natural gas sales apportioned to each industry subtype (manufacturing, construction, or mining, quarrying, and oil and gas).	Equation 8	MMcf
Total community employees $_{industry\ subtype}$	Estimated number of employees for the industry subtype at the community scale	Computed value; (U.S. Census Bureau, 2017)	employees
Total state employees $_{industry\ subtype}$	Estimated number of employees for the industry subtype within the state	Computed value; (U.S. Census Bureau, 2017)	employees
Community avg. employee intensity	Weighted average annual natural gas consumption per employee for the community (manufacturing only)	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee

State avg. employee intensity	Weighted average annual natural gas consumption per employee for the state (manufacturing only)	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee

Methodology Assumptions and Potential Improvement

General assumptions

- Categories of employees identified by NAICS classification codes in Census data and used to produce employee estimates align with categories included within the EIA industrial end-use category

Spatial assumptions

- The distribution of industrial natural gas consumption within a state is proportionally related to the distribution of industrial sector establishments and employees
- The distribution of industrial establishments and associated employees within a ZIP code territory is proportionally related to population distribution.
- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's Input-Output data at the national level, are applicable as allocation factors at a state level

Temporal assumptions

- MECS-derived average per-employee consumption figures by establishment size, sourced from 2010 data, serve as a viable proxy for average per-employee consumption in subsequent years
- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's 2007 Input-Output tables, serve as a viable proxy for relative consumption patterns in subsequent years
- All natural gas delivered to industrial customers is consumed within the year it was delivered

Potential Improvement

The method described above accounts for differences in energy consumption patterns by industry sub-type by establishing allocation factors for three industrial subcategories – manufacturing, construction, and mining, quarrying, and oil and gas – using BEA data tables. This allows for estimates that are more reflective of the fuel requirements of different industries, however the three categories remain quite broad, and a method that incorporates more granular subtypes – such as cement or steel – would be more desirable.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as economic output (either as a dollar value or physical units of production). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on industrial economic output, by contrast, is typically proprietary in the United States and thus is not an open data source.

Scope 1: Distillate Fuel Oil

Methodology Notes

Industrial sector distillate fuel oil[11] consumption is calculated using state-level distillate fuel oil sales data to industrial customers from the U.S. Energy Information Administration (EIA, 2017b) and supplementary Bureau of Economic Analysis data (BEA, 2014). These sales data are combined with computed ratios representing:

- the **proportion of employees** in the community relative to the state, and
- a computed **weighted average per-employee energy intensity** for the community relative to the state (done for manufacturing industry subtype only).

Various types of industry exhibit significantly different fuel consumption patterns, however EIA sales data are available only in aggregate and not broken-out by industry subtype. To address this, supplemental data are used to estimate and pull out the share of EIA state-level sales data comprised by three broad industrial subtypes: a) manufacturing, b) construction, and c) mining, quarrying, and oil and gas. The supplemental data used, BEA's *Input-Output* data tables, provide a representation of the flow of commodities between industries, identified by North American Industry Classification System (NAICS) IDs. The tables are used to estimate the relative share of total state fuel oil consumption that can be attributed to the three industry subtypes, resulting in separate totals for each at the state level.

Census data are used to estimate the number of employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code population residing within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that population serves as a viable proxy for the distribution of industrial establishments and employees. It is important to note that some ZIP codes containing industrial establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into industrial sector and non-industrial sector totals based on NAICS code. Total industrial employee estimates are further subdivided into separate totals for the manufacturing, construction, and mining, quarrying, and oil and gas NAICS codes. Estimates corresponding to NAICS codes falling outside of the industrial sector are filtered out and retained for other sub-sector estimates (see accompanying appendices).

Industrial sector employee totals are assumed to be a viable disaggregation factor for state-level EIA industry end-use sector distillate fuel oil sales. EIA guidance on the exact sub-categories encompassed by the industry end-use sector is limited, however reasonable assumptions are made regarding the general alignment of this end-use sector and the NAICS codes used for the industrial sector employee estimates. Figure C1 in Appendix C provides a simplified visual representation of how these data elements are mapped.

For the manufacturing industrial category only, distillate fuel oil consumption is allocated to the community not simply by relative consumption patterns of industry sub-types and the number of industrial sector employees, but also but by a **weighted average per-employee energy intensity** which takes into consideration the relative per-employee fuel intensity of establishments of different sizes. Weighted average per-employee intensities are calculated at the state and community level based on nine establishment size ranges matching those from the Census Business Patterns data described above (e.g. 1-4 employees, 5-9 employees, etc.). Average annual fuel oil consumption estimates (in MMBTU/employee) for each of the nine establishment size ranges, derived from the EIA Manufacturing Energy Consumption Survey (MECS) (EIA, 2017e), are matched to the number of employees corresponding to each establishment range to generate weighted average per-employee energy intensity figures. This is done so that estimates are more reflective of the establishment size context within individual communities, avoiding a uniform per-employee intensity across all communities and making the data more useful for comparison. Similar weights were not calculated for the construction or mining, quarrying and oil and gas industrial subtypes because EIA does not have equivalent data for these categories.

The below equation represents the calculation method utilized to apportion aggregate fuel oil sales for the industrial end-use sector at the state level into constituent industry subtypes (manufacturing, construction, and mining, quarrying, and oil and gas).

Equation 10

$$Aggregate\ state\ sales_{industrial\ subtype} = aggregate\ state\ sales_{industrial} \times \frac{national\ commodity\ consumption\ level_{industrial\ subtype}}{national\ commodity\ conslumption\ level_{industrial}}$$

Table B*17. Equation 10 Data Elements*

Data element	Description	Source	Units
Aggregate state sales $_{industrial\ subtype}$	Estimated amount of state level distillate fuel oil sales apportioned to industrial subtype (manufacturing, construction, or mining, quarrying, and oil and gas	Calculated	gallons
Aggregate state sales $_{industrial}$	Amount of distillate fuel oil distributed to all industrial customers within entire state	(EIA, 2017b)	gallons
National commodity consumption level $_{industrial\ subtype}$	Value of fuel oil commodity consumed at national scale for industry subtype	(BEA, 2014)	million USD

National commodity consumption level $_{industrial}$	Value of fuel oil commodity consumed at national scale for all industry.	(BEA, 2014)	million USD

The below equation represents the calculation method utilized to estimate total industrial sector fuel oil consumption at the community scale.

Equation 11

$$Community - scale\ industrial\ consumption = \sum_{industry\ subtype} \left(aggregate\ state\ sales_{industry\ subtype} \times \frac{total\ community\ employees_{industry\ subtype}}{total\ state\ employees_{industry\ subtype}} \times \frac{commnity\ avg.employee\ intensity}{state\ avg.employee\ intensity} \right)$$

Table B*18. Equation 11 Data Elements*

Data element	Description	Source	Units
Community-scale industrial consumption	All distillate fuel consumption within community boundary for a single year for all industrial establishments	Calculated	gallons
Aggregate state sales $_{industry\ subtype}$	Estimated amount of distillate fuel oil sales apportioned to each industry subtype (manufacturing, construction, or mining, quarrying, and oil and gas).	Equation 10	gallons
Total community employees $_{industry\ subtype}$	Estimated number of employees for the industry subtype at the community scale	Computed value; (U.S. Census Bureau, 2017)	employees
Total state employees $_{industry\ subtype}$	Estimated number of employees for the industry	Computed value; (U.S. Census Bureau, 2017)	employees

	subtype within the state		
Community avg. employee intensity	Weighted average annual fuel oil consumption per employee for the community (manufacturing only)	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee
State avg. employee intensity	Weighted average annual fuel oil consumption per employee for the state (manufacturing only)	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee

Methodology Assumptions and Potential Improvement

General assumptions

- Categories of employees identified by NAICS classification codes in Census data and used to produce employee estimates align with categories included within the EIA industrial end-use category

Spatial assumptions

- The distribution of industrial distillate fuel oil consumption within a state is proportionally related to the distribution of industrial sector establishments and employees
- The distribution of industrial establishments and associated employees within a ZIP code territory is proportionally related to population distribution.
- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's Input-Output data at the national level, are applicable as allocation factors at a state level

Temporal assumptions

- MECS-derived average per-employee consumption figures by establishment size, sourced from 2010 data, serve as a viable proxy for average per-employee consumption in subsequent years
- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's 2007 Input-Output tables, serve as a viable proxy for relative consumption patterns in subsequent years
- All distillate fuel oil delivered to industrial customers is consumed within the year it was delivered

Potential Improvement

The method described above accounts for differences in energy consumption patterns by industry sub-type by establishing allocation factors for three industrial subcategories – manufacturing, construction, and mining, quarrying, and oil and gas – using BEA data tables. This allows for estimates that are more reflective of the fuel requirements of different industries, however the three categories remain quite broad, and a method that incorporates more granular subtypes – such as cement or steel – would be more desirable.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as economic output (either as a dollar value or physical units of production). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on industrial economic output, by contrast, is typically proprietary in the United States and thus is not an open data source.

Scope 1: Residual Fuel Oil

Methodology Notes

Industrial sector residual fuel oil[12] consumption is calculated using state-level residual fuel oil sales data to industrial customers from the U.S. Energy Information Administration (EIA, 2017c) and supplementary Bureau of Economic Analysis data (BEA, 2014). These sales data are combined with computed ratios representing:

- the **proportion of employees** in the community relative to the state, and
- a computed **weighted average per-employee energy intensity** for the community relative to the state (done for manufacturing industry subtype only).

Various types of industry exhibit significantly different fuel consumption patterns, however EIA sales data are available only in aggregate and not broken-out by industry subtype. To address this, supplemental data are used to estimate and pull out the share of EIA state-level sales data comprised by three broad industrial subtypes: a) manufacturing, b) construction, and c) mining, quarrying, and oil and gas. The supplemental data used, BEA's *Input-Output* data tables, provide a representation of the flow of commodities between industries, identified by North American Industry Classification System (NAICS) IDs. The tables are used to estimate the relative share of total state fuel oil consumption that can be attributed to the three industry subtypes, resulting in separate totals for each at the state level.

Census data are used to estimate the number of employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code population residing within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that population serves as a viable proxy for the distribution of industrial establishments and employees. It is important to note that some ZIP codes containing industrial establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into industrial sector and non-industrial sector totals based on NAICS code. Total industrial employee estimates are further subdivided into separate totals for the manufacturing, construction, and mining, quarrying, and oil and gas NAICS codes. Estimates corresponding to NAICS codes falling outside of the industrial sector are filtered out and retained for other sub-sector estimates (see accompanying appendices).

Industrial sector employee totals are assumed to be a viable disaggregation factor for state-level EIA industry end-use sector residual fuel oil sales. EIA guidance on the exact sub-categories encompassed by the industry end-use sector is limited, however reasonable assumptions are made regarding the general alignment of this end-use sector and the NAICS codes used for the industrial sector employee estimates. Figure C1 in Appendix C provides a simplified visual representation of how these data elements are mapped.

For the manufacturing industrial category only, residual fuel oil consumption is allocated to the community not simply by relative consumption patterns of industry sub-types and the number of industrial sector employees, but also but by a **weighted average per-employee energy intensity** which takes into consideration the relative per-employee fuel intensity of establishments of different sizes. Weighted average per-employee intensities are calculated at the state and community level based on nine establishment size ranges matching those from the Census Business Patterns data described above (e.g. 1-4 employees, 5-9 employees, etc.). Average annual fuel oil consumption estimates (in MMBTU/employee) for each of the nine establishment size ranges, derived from the EIA Manufacturing Energy Consumption Survey (MECS) (EIA, 2017e), are matched to the number of employees corresponding to each establishment range to generate weighted average per-employee energy intensity figures. This is done so that estimates are more reflective of the establishment size context within individual communities, avoiding a uniform per-employee intensity across all communities and making the data more useful for comparison. Similar weights were not calculated for the construction or mining, quarrying and oil and gas industrial subtypes because EIA does not have equivalent data for these categories.

The below equation represents the calculation method utilized to apportion aggregate fuel oil sales for the industrial end-use sector at the state level into constituent industry subtypes (manufacturing, construction, and mining, quarrying, and oil and gas).

Equation 12

$$Aggregate\ state\ sales_{industrial\ subtype} = aggregate\ state\ sales_{industrial} \times \frac{national\ commodity\ consumption\ level_{industrial\ subtype}}{national\ commodity\ conslumption\ level_{industrial}}$$

Table B*19. Equation 12 Data Elements*

Data element	Description	Source	Units
Aggregate state sales $_{industrial\ subtype}$	Estimated amount of state level residual fuel oil sales apportioned to industrial subtype (manufacturing,	Calculated	gallons

	construction, or mining, quarrying, and oil and gas		
Aggregate state sales $_{industrial}$	Amount of residual fuel oil distributed to all industrial customers within entire state	(EIA, 2017c)	gallons
National commodity consumption level $_{industrial\ subtype}$	Value of fuel oil commodity consumed at national scale for industry subtype	(BEA, 2014)	million USD
National commodity consumption level $_{industrial}$	Value of fuel oil commodity consumed at national scale for all industry.	(BEA, 2014)	million USD

The below equation represents the calculation method utilized to estimate total industrial sector fuel oil consumption at the community scale.

Equation 13

$$Community - scale\ industrial\ consumption = \sum_{industry\ subtype} \left(aggregate\ state\ sales_{industry\ subtype} \times \frac{total\ community\ employees_{industry\ subtype}}{total\ state\ employees_{industry\ subtype}} \times \frac{commnity\ avg.employee\ intensity}{state\ avg.employee\ intensity} \right)$$

Table B*20. Equation 13 Data Elements*

Data element	Description	Source	Units
Community-scale industrial consumption	All residual fuel consumption within community boundary for a single year for all industrial establishments	Calculated	gallons
Aggregate state sales $_{industry\ subtype}$	Estimated amount of residual fuel oil sales allocated to each industry subtype (manufacturing, construction, or	Equation 12	gallons

	mining, quarrying, and oil and gas).		
Total community employees $_{\text{industry subtype}}$	Estimated number of employees for the industry subtype at the community scale	Computed value; (U.S. Census Bureau, 2017)	employees
Total state employees $_{\text{industry subtype}}$	Estimated number of employees for the industry subtype within the state	Computed value; (U.S. Census Bureau, 2017)	employees
Community avg. employee intensity	Weighted average annual fuel oil consumption per employee for the community (manufacturing only)	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee
State avg. employee intensity	Weighted average annual fuel oil consumption per employee for the state (manufacturing only)	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee

Methodology Assumptions and Potential Improvement

General assumptions

- Categories of employees identified by NAICS classification codes in Census data and used to produce employee estimates align with categories included within the EIA industrial end-use category

Spatial assumptions

- The distribution of industrial residual fuel oil consumption within a state is proportionally related to the distribution of industrial sector establishments and employees
- The distribution of industrial establishments and associated employees within a ZIP code territory is proportionally related to population distribution.
- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's Input-Output data at the national level, are applicable as allocation factors at a state level

Temporal assumptions

- MECS-derived average per-employee consumption figures by establishment size, sourced from 2010 data, serve as a viable proxy for average per-employee consumption in subsequent years
- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's 2007 Input-Output tables, serve as a viable proxy for relative consumption patterns in subsequent years
- All residual fuel oil delivered to industrial customers is consumed within the year it was delivered

Potential Improvement

The method described above accounts for differences in energy consumption patterns by industry sub-type by establishing allocation factors for three industrial subcategories – manufacturing, construction, and mining, quarrying, and oil and gas – using BEA data tables. This allows for estimates that are more reflective of the fuel requirements of different industries, however the three categories remain quite broad, and a method that incorporates more granular subtypes – such as cement or steel – would be more desirable.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as economic output (either as a dollar value or physical units of production). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on industrial economic output, by contrast, is typically proprietary in the United States and thus is not an open data source.

Scope 1: Kerosene

Methodology Notes

Industrial sector kerosene[13] consumption is calculated using state-level kerosene sales data to industrial customers from the U.S. Energy Information Administration (EIA, 2017d) and supplementary Bureau of Economic Analysis data (BEA, 2014). These sales data are combined with computed ratios representing:

- the **proportion of employees** in the community relative to the state, and
- a computed **weighted average per-employee energy intensity** for the community relative to the state (done for manufacturing industry subtype only).

Various types of industry exhibit significantly different fuel consumption patterns, however EIA sales data are available only in aggregate and not broken-out by industry subtype. To address this, supplemental data are used to estimate and pull out the share of EIA state-level sales data comprised by three broad industrial subtypes: a) manufacturing, b) construction, and c) mining, quarrying, and oil and gas. The supplemental data used, BEA's *Input-Output* data tables, provide a representation of the flow of commodities between industries, identified by North American Industry Classification System (NAICS) IDs. The tables are used to estimate the relative share of total state fuel consumption that can be attributed to the three industry subtypes, resulting in separate totals for each at the state level.

Census data are used to estimate the number of employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees;

250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code population residing within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that population serves as a viable proxy for the distribution of industrial establishments and employees. It is important to note that some ZIP codes containing industrial establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into industrial sector and non-industrial sector totals based on NAICS code. Total industrial employee estimates are further subdivided into separate totals for the manufacturing, construction, and mining, quarrying, and oil and gas NAICS codes. Estimates corresponding to NAICS codes falling outside of the industrial sector are filtered out and retained for other sub-sector estimates (see accompanying appendices).

Industrial sector employee totals are assumed to be a viable disaggregation factor for state-level EIA industry end-use sector kerosene sales. EIA guidance on the exact sub-categories encompassed by the industry end-use sector is limited, however reasonable assumptions are made regarding the general alignment of this end-use sector and the NAICS codes used for the industrial sector employee estimates. Figure C1 in Appendix C provides a simplified visual representation of how these data elements are mapped.

For the manufacturing industrial category only, kerosene consumption is allocated to the community not simply by relative consumption patterns of industry sub-types and the number of industrial sector employees, but also but by a **weighted average per-employee energy intensity** which takes into consideration the relative per-employee fuel intensity of establishments of different sizes. Weighted average per-employee intensities are calculated at the state and community level based on nine establishment size ranges matching those from the Census Business Patterns data described above (e.g. 1-4 employees, 5-9 employees, etc.). Average annual fuel consumption estimates (in MMBTU/employee) for each of the nine establishment size ranges, derived from the EIA Manufacturing Energy Consumption Survey (MECS) (EIA, 2017e), are matched to the number of employees corresponding to each establishment range to generate weighted average per-employee energy intensity figures. This is done so that estimates are more reflective of the establishment size context within individual communities, avoiding a uniform per-employee intensity across all communities and making the data more useful for comparison. Similar weights were not calculated for the construction or mining, quarrying and oil and gas industrial subtypes because EIA does not have equivalent data for these categories.

The below equation represents the calculation method utilized to apportion aggregate kerosene sales for the industrial end-use sector at the state level into constituent industry subtypes (manufacturing, construction, and mining, quarrying, and oil and gas).

Equation 14

$$Aggregate\ state\ sales_{industrial\ subtype} = aggregate\ state\ sales_{industrial} \times \frac{national\ commodity\ consumption\ level_{industrial\ subtype}}{national\ commodity\ conslumption\ level_{industrial}}$$

Table B21. *Equation 14 Data Elements*

Data element	Description	Source	Units
Aggregate state sales $_{industrial\ subtype}$	Estimated amount of state level kerosene sales allocated to industrial subtype (e.g. manufacturing, construction, mining, quarrying, and oil and gas	Calculated	gallons
Aggregate state sales $_{industrial}$	Amount of kerosene distributed to all industrial customers within entire state	(EIA, 2017d)	gallons
National commodity consumption level $_{industrial\ subtype}$	Level of fuel oil commodity consumed at national scale for industry subtype	(BEA, 2014)	million USD
National commodity consumption level $_{industrial}$	Level of fuel oil commodity consumed at national scale for all industry	(BEA, 2014)	million USD

The below equation represents the calculation method utilized to estimate total industrial sector kerosene consumption at the community scale.

Equation 15

$$Community - scale\ industrial\ consumption = \sum_{industry\ subtype} \left(aggregate\ state\ sales_{industry\ subtype} \times \frac{total\ community\ employees_{industry\ subtype}}{total\ state\ employees_{industry\ subtype}} \times \frac{commnity\ avg.employee\ intensity}{state\ avg.employee\ intensity} \right)$$

Table B22. *Equation 15 Data Elements*

Data element	Description	Source	Units
Community-scale industrial consumption	All kerosene consumption within community boundary for a	Calculated	gallons

	single year for all industrial establishments		
Aggregate state sales $_{\text{industry subtype}}$	Estimated amount of kerosene sales apportioned to each industry subtype (manufacturing, construction, or mining, quarrying, and oil and gas).	Equation 14	gallons
Total community employees $_{\text{industry subtype}}$	Estimated number of employees for the industry subtype at the community scale	Computed value; (U.S. Census Bureau, 2017)	employees
Total state employees $_{\text{industry subtype}}$	Estimated number of employees for the industry subtype within the state	Computed value; (U.S. Census Bureau, 2017)	employees
Community avg. employee intensity	Weighted average annual kerosene consumption per employee for the community (manufacturing only)	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee
State avg. employee intensity	Weighted average annual kerosene consumption per employee for the state (manufacturing only)	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee

Methodology Assumptions and Potential Improvement

General assumptions

- Categories of employees identified by NAICS classification codes in Census data and used to produce employee estimates align with categories included within the EIA industrial end-use category

Spatial assumptions

- The distribution of industrial kerosene consumption within a state is proportionally related to the distribution of industrial sector establishments and employees
- The distribution of industrial establishments and associated employees within a ZIP code territory is proportionally related to population distribution.
- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's Input-Output data at the national level, are applicable as allocation factors at a state level

Temporal assumptions

- MECS-derived average per-employee consumption figures by establishment size, sourced from 2010 data, serve as a viable proxy for average per-employee consumption in subsequent years
- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's 2007 Input-Output tables, serve as a viable proxy for relative consumption patterns in subsequent years
- All kerosene delivered to industrial customers is consumed within the year it was delivered

Potential Improvement

The method described above accounts for differences in energy consumption patterns by industry sub-type by establishing allocation factors for three industrial subcategories – manufacturing, construction, and mining, quarrying, and oil and gas – using BEA data tables. This allows for estimates that are more reflective of the fuel requirements of different industries, however the three categories remain quite broad, and a method that incorporates more granular subtypes – such as cement or steel – would be more desirable.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as economic output (either as a dollar value or physical units of production). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on industrial economic output, by contrast, is typically proprietary in the United States and thus is not an open data source.

Scope 2: Electricity

Methodology Notes

Industrial sector electricity consumption is calculated using state-level electricity sales data to industrial customers from the U.S. Energy Information Administration (EIA, 2017f) and supplementary Economic Census data (U.S. Census Bureau, 2015). These sales data are combined with computed ratios representing:

- the **proportion of employees** in the community relative to the state, and
- a computed **weighted average per-employee energy intensity** for the community relative to the state (done for manufacturing industry subtype only).

State-level sales data for the industrial sector is calculated as the sum of all sales (in MWh), for EIA 861 parts A and C only, for the industrial end-use category.

Various types of industry exhibit significantly different electricity consumption patterns, however EIA sales data are available only in aggregate and not broken-out by industry subtype. To address this, supplemental data are used to estimate and pull out the share of EIA state-level sales data comprised by three broad industrial subtypes: a) manufacturing, b) construction, and c) mining, quarrying, and oil and gas. The supplemental data used, Economic Census annual expenditure data, provide estimates of aggregate expenditures on various commodities (including electricity) across industries, identified by North American Industry Classification System (NAICS) IDs. The data are used to estimate the relative share of total state electricity consumption that can be attributed to the three industry subtypes, resulting in separate totals for each at the state level.

Census data are used to estimate the number of employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code population residing within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that population serves as a viable proxy for the distribution of industrial establishments and employees. It is important to note that some ZIP codes containing industrial establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into industrial sector and non-industrial sector totals based on NAICS code. Total industrial employee estimates are further subdivided into separate totals for the manufacturing, construction, and mining, quarrying, and oil and gas NAICS codes. Estimates corresponding to NAICS codes falling outside of the industrial sector are filtered out and retained for other sub-sector estimates (see accompanying appendices).

Industrial sector employee totals are assumed to be a viable disaggregation factor for state-level EIA industry end-use sector electricity sales. EIA guidance on the exact sub-categories encompassed by the industry end-use sector is limited, however reasonable assumptions are made regarding the general alignment of this end-use sector and the NAICS codes used for the industrial sector employee estimates. Figure C1 in Appendix C provides a simplified visual representation of how these data elements are mapped.

For the manufacturing industrial category only, electricity consumption is allocated to the community not simply by relative consumption patterns of industry sub-types and the number of industrial sector employees, but also but by a **weighted average per-employee energy intensity** which takes into consideration the relative per-employee electricity intensity of establishments of different sizes. Weighted average per-employee intensities are calculated at the state and community level based on nine establishment size ranges matching those from the Census Business Patterns data described above (e.g. 1-4 employees, 5-9 employees, etc.). Average annual electricity consumption estimates (in

MMBTU/employee) for each of the nine establishment size ranges, derived from the EIA Manufacturing Energy Consumption Survey (MECS) (EIA, 2017e), are matched to the number of employees corresponding to each establishment range to generate weighted average per-employee energy intensity figures. This is done so that estimates are more reflective of the establishment size context within individual communities, avoiding a uniform per-employee intensity across all communities and making the data more useful for comparison. Similar weights were not calculated for the construction or mining, quarrying and oil and gas industrial subtypes because EIA does not have equivalent data for these categories.

The below equation represents the calculation method utilized to apportion aggregate electricity sales for the industrial end-use sector at the state level into constituent industry subtypes (manufacturing, construction, and mining, quarrying, and oil and gas).

Equation 16

$$Aggregate\ state\ sales_{industrial\ subtype} = aggregate\ state\ sales_{industrial} \times \frac{state\ electricity\ consumption_{industrial\ subtype}}{total\ state\ electricity\ conslumption_{industrial}}$$

Table B23. ***Equation 16 Data Elements***

Data element	Description	Source	Units
Aggregate state sales$_{industrial\ subtype}$	Estimated amount of state electricity sales allocated to industrial subtype (manufacturing, construction, or mining, quarrying, and oil and gas	Calculated	mwh
Aggregate state sales$_{industrial}$	Amount of electricity sold to all industrial customers within entire state	(EIA, 2017f)	mwh
State electricity consumption level$_{industrial\ subtype}$	Consumption of electricity as a commodity for the industry subtype according to economic census.	(U.S. Census Bureau, 2015)	USD (converted to mwh)
Total state electricity consumption level$_{industrial}$	Total consumption of electricity as a commodity for all industry subtypes according to economic census.	(U.S. Census Bureau, 2015)	USD (converted to mwh)

The below equation represents the calculation method utilized to estimate total industrial sector electricity consumption at the community scale.

Equation 17

$$Community\ scale\ industrial\ consumption = \sum_{industry\ subtype} \left(aggregate\ state\ sales_{industry\ subtype} \times \frac{total\ community\ employees_{industry\ subtype}}{total\ state\ employees_{industry\ subtype}} \times \frac{commnity\ avg.employee\ intensity}{state\ avg.employee\ intensity} \right)$$

Table B24. ***Equation 17 Data Elements***

Data element	Description	Source	Units
Community-scale industrial consumption	All electricity consumption within community boundary for a single year for all industrial establishments	Calculated	mwh
Aggregate state sales $_{industry\ subtype}$	Estimated amount of electricity sales apportioned to each industry subtype (manufacturing, construction, or mining, quarrying, and oil and gas).	Equation 16	mwh
Total community employees $_{industry\ subtype}$	Estimated number of employees for the industry subtype at the community scale	Computed value; (U.S. Census Bureau, 2017)	employees
Total state employees $_{industry\ subtype}$	Estimated number of employees for the industry subtype within the state	Computed value; (U.S. Census Bureau, 2017)	employees
Community avg. employee intensity	Weighted average annual electricity consumption per employee for the community	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee

	(manufacturing only)		
State avg. employee intensity	Weighted average annual electricity consumption per employee for the state (manufacturing only)	Computed value; (U.S. Census Bureau, 2017); (EIA, 2017e)	MMBTU/ employee

Methodology Assumptions and Potential Improvement

General assumptions

- Categories of employees identified by NAICS classification codes in Census data and used to produce employee estimates align with categories included within the EIA industrial end-use category

Spatial assumptions

- The distribution of electricity consumption within a state is proportionally related to the distribution of industrial sector establishments and employees
- The distribution of industrial establishments and associated employees within a ZIP code territory is proportionally related to population distribution.

Temporal assumptions

- MECS-derived average per-employee consumption figures by establishment size, sourced from 2010 data, serve as a viable proxy for average per-employee consumption in subsequent years
- Relative industrial consumption patterns by subtype (e.g. the share of electricity consumed by manufacturing vs. construction), derived from Economic Census data, serve as a viable proxy for relative consumption patterns in subsequent years

Limitations

- Consumption data does not include electricity from on-site generation

Potential Improvement

The method described above accounts for differences in energy consumption patterns by industry sub-type by establishing allocation factors for three industrial subcategories – manufacturing, construction, and mining, quarrying, and oil and gas – using Economic Census data. This allows for estimates that are more reflective of the energy requirements of different industries, however the three categories remain quite broad, and a method that incorporates more granular subtypes – such as cement or steel – would be more desirable.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as economic output (either as a dollar value or physical units of production). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on industrial economic output, by contrast, is typically proprietary in the United States and thus is not an open data source.

Table B25. Emission Factors:

Fuel Type	kg CO_2 per scf	g CH_4 per scf	g N_2O per scf	Source
Natural Gas	0.05444	0.00103	0.00010	(EPA, 2015)

Fuel Type	kg CO_2 per gallon	g CH_4 per gallon	g N_2O per gallon	Source
Distillate Fuel Oil[14]	10.45	0.42	0.08	(EPA, 2015)
Kerosene	10.15	0.41	0.08	(EPA, 2015)
Residual Fuel Oil	10.74	0.44	0.09	(EPA, 2015)

Grid Electricity	See Appendix E

Sources: EPA 2015 (natural gas, distillate fuel oil); EPA 2018 (grid electricity)

References:

Bureau of Economic Analysis (BEA). (2014). Input-Output Accounts Data: Use Tables – 2007. Release date: 11/13/14. Retrieved from: https://www.bea.gov/industry/io_annual.htm

Provides estimates on the flow of commodities between industries, used to estimate the relative fuel consumption patterns of different industrial categories (e.g. manufacturing, construction, agriculture)

EIA. (2017a). Natural Gas Consumption by End Use. Release date: 12/29/2017. Retrieved from: https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm

Provides state-level natural gas sales totals by end-use category, which are disaggregated to the community-scale.

EIA. (2017b). Sales of Distillate Fuel Oil by End Use. Release date: 12/19/2017. Retrieved from: https://www.eia.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm

Provides state-level fuel oil sales totals by end-use category, which are disaggregated to the community scale.

EIA. (2017c). Sales of Residual Fuel Oil by End Use. Release date: 12/19/2017. Retrieved from: https://www.eia.gov/dnav/pet/pet_cons_821rsd_dcu_nus_a.htm

Provides state-level fuel oil sales totals by end-use category, which are disaggregated to the community scale.

EIA. (2017d). Sales of Kerosene by End Use. Release date: 12/19/2017. Retrieved from: https://www.eia.gov/dnav/pet/pet_cons_821ker_dcu_nus_a.htm

Provides state-level kerosene sales totals by end-use category, which are disaggregated to the community scale.

EIA. (2017e). Manufacturing Energy Consumption Survey (MECS). 2014 MECS Survey Data – Table 6.4 By Mfg. Industry & Employment Size. Release date: 11/2017. Retrieved from: https://www.eia.gov/consumption/manufacturing/data/2014/#r6

Used to develop regional weights based on the number of employees in various manufacturing establishment size classes (e.g. 1-4 employees, 50-100 employees, etc.)

EIA. (2017f). Form EIA-861 detailed data files. Sales to Ultimate Customers. Release date: 11/6/17. Retrieved from: https://www.eia.gov/electricity/data/eia861/

Provides state-level electricity sales totals by end-use category, which are disaggregated to the community-scale.

EPA. (2015). Emission Factors for Greenhouse Gas Inventories. EPA Center for Corporate Climate Leadership. Last modified: 11/19/15. Retrieved from: https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

Provides U.S.-specific emission factors for the combustion of fuels included in the methodology.

EPA. (2018). Emissions & Generation Resource Integrated Database (eGRID). eGRID 2016. Released: 2/15/2018. Retrieved from: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Provides U.S. grid region-specific emission factors for electricity consumption.

U.S. Census Bureau. (2015). 2012 Economic Census of the United States. Release date: 6/16/15. Retrieved from: https://www.census.gov/programs-surveys/economic-census/data/tables.2012.html

Provides estimates on the average annual electricity expenditures of various industries, used to estimate the relative consumption patterns of different industrial categories (e.g. manufacturing, construction, agriculture)

U.S. Census Bureau. (2017). CBP Datasets - 2015: Complete ZIP Code Industry Detail File; Complete ZIP Code Totals File. Released 4/20/17. Retrieved from: https://www.census.gov/data/datasets/2015/econ/cbp/2015-cbp.html

Used to estimate the number of commercial sector employees, by establishment size, at the ZIP code level.

Agriculture, Forestry, and Fishing

Subsector Summary:

The agriculture, forestry, and fishing subsector comprises all emissions from energy use associated with agriculture, forestry, and fishing (AFF) activities, including heating, cooling, lighting, irrigation, and the operation of machinery. The two primary categories of GHG emitting activities within the subsector are: scope 1 emissions from fuel combustion associated with AFF activities within the community boundary and scope 2 emissions from consumption of grid-supplied energy.

Inclusions:

For the United States, based on data availability and occurrence in-country, estimates for the following activity data points were produced:

- **Natural gas**, **distillate fuel oil**, and **kerosene** consumption associated with agriculture, forestry, and fishing activities, based on annual fuel sales to agriculture, forestry and fishing customers in each U.S. state
- **Electricity** consumption associated with agriculture, forestry, and fishing activities, based on annual electricity sales to agriculture, forestry, and fishing customers in each U.S. state

Exclusions:

Due to lack of data availability or occurrence in-country, estimates for the following activity data points were not produced:

- **Off-highway motor gasoline** consumption, e.g. for use in tractors, mowers, and other equipment
- **District heating, cooling,** or other non-electricity grid-supplied energy

The specific data points covered by the methodology are outlined in the table below.

Table B26. Activity Data Coverage:

Fuels/Energy Source	Definition	Units	Scope
Natural Gas	All natural gas consumption within community boundary for a single year associated with agriculture, forestry, and fishing activities	MMcf	Scope 1
Distillate Fuel Oil	All distillate fuel oil consumption within community boundary for a single year associated with agriculture, forestry, and fishing activities	thousand gallons	
Kerosene	All kerosene consumption within community boundary for a single year associated with agriculture, forestry, and fishing activities	thousand gallons	

Electricity	All grid-supplied electricity consumption within community boundary for a single year associated with agriculture, forestry, and fishing activities	MWh	Scope 2

Calculation Methodologies:

Scope 1: Natural Gas

Methodology Notes

Agriculture, forestry, and fisheries (AFF) sector natural gas consumption is calculated using state-level natural gas sales data to industrial customers from the U.S. Energy Information Administration (EIA, 2017a) and supplementary Bureau of Economic Analysis data (BEA, 2014). These sales data are combined with a computed ratio representing the proportion of employees in the community relative to the state to estimate consumption at the community scale.

State level EIA Natural Gas sales data includes AFF-specific end-uses within the broader *industrial* category of end-uses rather than as a separate category. To address this, EIA state-level sales data for the industrial sector is first subdivided into AFF and non-AFF totals. BEA provides *Input-Output* tables estimate the flow of commodities between industries, identified by North American Industry Classification System (NAICS) IDs, and are used to estimate the share of total state natural gas apportionable to AFF and non-AFF industrial end-users.

Census data are used to estimate the number of AFF employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code land area within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that land area serves as a viable proxy for the distribution of AFF establishments and employees. It is important to note that some ZIP codes containing AFF establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into AFF and non-AFF sector totals based on NAICS code. Estimates corresponding to NAICS codes falling outside of the AFF sector are filtered out and retained for other sub-sector estimates (see accompanying appendices).

AFF sector employee totals are assumed to be a viable disaggregation factor for state-level EIA natural gas sales, after filtering out the share consumed by non-AFF industries. EIA guidance on the exact sub-categories encompassed by its end-use sectors is limited, however reasonable assumptions are made regarding alignment with the NAICS codes used for the AFF sector employee estimates. Figure C1 in Appendix C provides a simplified visual representation of how these data elements are mapped.

The below equation represents the calculation method utilized to estimate the share of aggregate natural gas sales for the industrial end-use sector attributable to AFF establishments.

Equation 18

$$Aggregate\ state\ sales_{AFF} = aggregate\ state\ sales_{industrial} \times \frac{national\ commodity\ consumption\ level_{AFF}}{national\ commodity\ conslumption\ level_{industrial}}$$

Table B27. *Equation 18 Data Elements*

Data element	Description	Source	Units
Aggregate state sales $_{AFF}$	Estimated amount of state level natural gas sales apportioned agriculture, forestry, and fisheries sector.	Calculated	MMcf
Aggregate state sales $_{industrial}$	Amount of natural gas distributed to all industrial customers within entire state	(EIA, 2017a)	MMcf
National commodity consumption level $_{AFF}$	Level of natural gas commodity consumed at national scale for industry subtype	(BEA, 2014)	million USD
National commodity consumption level $_{industrial}$	Level of natural gas commodity consumed at national scale for all industry	(BEA, 2014)	million USD

The below equation represents the calculation method utilized to estimate agriculture, forestry, and fishing (AFF) sector natural gas consumption at the community scale.

Equation 19

$$Community - scale\ natural\ gas\ consumption_{AFF} = \text{aggregate state sales}_{\text{AFF}} \times \left(\frac{\text{total community employees}_{\text{AFF}}}{\text{total state employees}_{\text{AFF}}}\right)$$

Table B28. *Equation Data Elements*

Data element	Description	Source	Units
Community-scale	All natural gas consumption within community boundary for a single	Equation 19	MMcf

consumption AFF	year for all agriculture, forestry, and fishing establishments		
Aggregate state sales AFF	Estimated amount of natural gas consumed by agriculture, forestry, and fishing establishments within entire state	Equation 18	MMcf
Total community employees AFF	Estimated number of agriculture, forestry, and fishing sector employees within the community	Computed value; (U.S. Census Bureau, 2017)	employees
Total state employees AFF	Estimated number of agriculture, forestry, and fishing sector employees within the state	Computed value; (U.S. Census Bureau, 2017)	employees

Methodology Assumptions and Potential Improvement

General assumptions

- Categories of employees identified by NAICS classification codes in Census data and used to produce employee estimates align with categories included within the EIA industrial end-use category

Spatial assumptions

- The distribution of AFF natural gas consumption within a state is proportionally related to the distribution of AFF sector establishments and employees
- The distribution of AFF establishments and associated employees within a ZIP code territory is proportionally related to land area distribution.
- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's Input-Output data at the national level, are applicable as allocation factors at a state level

Temporal assumptions

- Relative consumption patterns by the AFF sector and other industrial subtypes (e.g. the share of fuel consumed by AFF, manufacturing, or construction), derived from BEA's 2007 Input-Output tables, serve as a viable proxy for relative consumption patterns in subsequent years
- All natural gas delivered to AFF customers is consumed within the year it was delivered

Potential Improvement

The method described above accounts for differences in energy consumption patterns by AFF and other industry subtypes by establishing allocation factors using BEA data tables. This allows for estimates that are more reflective of the fuel requirements of different industries, however these categories remain quite broad, and a method that incorporates more granular subtypes with different energy needs – such as logging and crop production – would be more desirable.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as economic output (either as a dollar value or physical units of production). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S.

Census estimates. Community scale information on AFF economic output, by contrast, is typically proprietary in the United States and thus is not an open data source.

Scope 1: Distillate Fuel Oil

Methodology Notes

Agriculture, forestry, and fisheries (AFF) sector distillate fuel oil consumption is calculated using state-level distillate fuel oil sales data to farm customers from the U.S. Energy Information Administration (EIA, 2017b) and a computed ratio representing the estimated number employees at the community scale versus the state.

State level EIA Distillate Fuel Oil sales data includes farm[15] as a distinct end-use category with its own sectoral sales total separate from other economic sectors. Without supplemental data on other AFF sector distillate fuel oil consumption beyond this category, it is assumed that farm consumption encompasses the clear majority of agricultural distillate fuel oil use, as well as distillate fuel oil use in the AFF sector more broadly.

Census data are used to estimate the number of AFF employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code land area within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that land area serves as a viable proxy for the distribution of AFF establishments and employees. It is important to note that some ZIP codes containing AFF establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into AFF and non-AFF sector totals based on NAICS code. Estimates corresponding to NAICS codes falling outside of the AFF sector are filtered out and retained for other sub-sector estimates (see accompanying appendices).

The below equation represents the calculation method utilized to estimate agriculture, forestry, and fishing (AFF) sector distillate fuel oil consumption at the community scale.

Equation 20

$$\text{Community-scale AFF consumption} = \text{aggregate state sales}_{\text{farm}} \times \left(\frac{\text{sector employees}_{\text{community}}}{\text{sector employees}_{\text{state}}}\right)$$

Table B*29. Equation Data Elements*

Data element	Description	Source	Units
Community-scale AFF consumption	All distillate fuel oil consumption within community boundary for a single year for all agriculture, forestry, and fishing establishments	Equation 20	gallons
Aggregate state sales $_{\text{farm}}$	Estimated amount of distillate fuel oil delivered to farm end-uses at the state level	(EIA, 2017b)	gallons
Total community employees $_{\text{AFF}}$	Estimated number of agriculture, forestry, and fishing sector employees within the community.	Computed value; (U.S. Census Bureau, 2017)	employees
Total state employees $_{\text{AFF}}$	Estimated number of agriculture, forestry, and fishing sector employees within the state.	Computed value; (U.S. Census Bureau, 2017)	employees

Methodology Assumptions and Potential Improvement

General assumptions

- EIA's "farm" end-use category sufficiently encompasses the majority of all state level distillate fuel oil consumption for the AFF sector more broadly.
- AFF sector establishment and employee totals derived from Census data serve as a viable disaggregation factor for total fuel oil sales to the farm end-use sector

Spatial assumptions

- The distribution of AFF distillate fuel oil consumption within a state is proportionally related to the distribution of AFF sector establishments and employees
- The distribution of AFF establishments and associated employees within a ZIP code territory is proportionally related to land area distribution.

Temporal assumptions

- All fuel oil delivered to AFF customers is consumed within the year it was delivered

Potential Improvement

While the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as economic output (either as a dollar value or physical units of production). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on AFF economic output, by contrast, is typically proprietary in the United States and thus is not an open data source.

Scope 1: Kerosene

Methodology Notes

Agriculture, forestry, and fisheries (AFF) sector kerosene consumption is calculated using state-level sales data to farm customers from the U.S. Energy Information Administration (EIA, 2017c) and a computed ratio representing the estimated number employees at the community scale versus the state.

State level EIA Kerosene sales data includes farm as a distinct end-use category with its own sectoral sales total separate from other economic sectors. Without supplemental data on other AFF sector kerosene consumption beyond this category, it is assumed that farm consumption encompasses the vast majority of agricultural kerosene use, as well as kerosene use in the AFF sector more broadly.

Census data are used to estimate the number of AFF employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code land area within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that land area serves as a viable proxy for the distribution of AFF establishments and employees. It is important to note that some ZIP codes containing AFF establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate in order to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into AFF and non-AFF sector totals based on NAICS code. Estimates corresponding to NAICS codes falling outside of the AFF sector are filtered out and retained for other sub-sector estimates (see accompanying appendices).

The below equation represents the calculation method utilized to estimate agriculture, forestry, and fishing (AFF) sector kerosene consumption at the community scale.

Equation 21

$$\text{Community-scale AFF consumption} = \text{aggregate state sales}_{\text{farm}} \times \left(\frac{\text{sector employees}_{\text{community}}}{\text{sector employees}_{\text{state}}}\right)$$

Table B*30. Equation 21 Data Elements*

Data element	Description	Source	Units
Community-scale AFF consumption	All kerosene consumption within community boundary for a single year for all agriculture, forestry, and fishing establishments	Calculated	gallons
Aggregate state sales $_{farm}$	Estimated amount of kerosene delivered to farm end-uses at the state level	(EIA, 2017c)	gallons
Total community employees $_{AFF}$	Estimated number of agriculture, forestry, and fishing sector employees within the community	Computed value; (U.S. Census Bureau, 2017)	employees
Total state employees $_{AFF}$	Estimated number of agriculture, forestry, and fishing sector employees within the state	Computed value; (U.S. Census Bureau, 2017)	employees

Methodology Assumptions and Potential Improvement

General assumptions

- EIA's "farm" end-use category sufficiently encompasses the majority of all state level kerosene consumption for the AFF sector more broadly.
- AFF sector establishment and employee totals derived from Census data serve as a viable disaggregation factor for total kerosene sales to the farm end-use sector.

Spatial assumptions

- The distribution of AFF kerosene consumption within a state is proportionally related to the distribution of AFF sector establishments and employees.
- The distribution of AFF establishments and associated employees within a ZIP code territory is proportionally related to land area distribution.

Temporal assumptions

- All kerosene delivered to AFF customers is consumed within the year it was delivered

Potential Improvement

While the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as economic output (either as a dollar value or physical units of production). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on AFF economic output, by contrast, is typically proprietary in the United States and thus is not an open data source.

Scope 2: Electricity

Methodology Notes

Agriculture, forestry, and fisheries (AFF) sector electricity consumption is calculated using state-level electricity sales data to industrial customers from the U.S. Energy Information Administration (EIA, 2017d), along with supplementary Economic Census data (U.S. Census Bureau, 2015) to disaggregate sales to AFF establishments from the industrial total. These sales data are combined with a computed ratio representing the estimated number employees at the community scale versus the state. State-level sales data for the industrial sector is calculated as the sum of all sales (in MWh), for EIA 861 parts A and C only.

State level EIA 861 electricity sales data includes agricultural end-uses within the broader industrial category of end-uses rather than as a separate category. Estimated non-AFF sector electricity consumption is therefore subtracted out to produce an estimated state total for the AFF sector. As detailed in the accompanying appendix on industrial sector estimates, data on manufacturing, construction, and mining, quarrying, oil and gas industry annual state-level electricity expenditures (U.S. Census Bureau, 2015) are used to calculate the relative share of sales to be apportioned to these industrial subtypes. This process results in a remainder that is allocated to the AFF sector. Because EIA does not list additional end-use subcategories beyond AFF, manufacturing, construction, and mining, quarrying, and oil and gas in its general guidance on the industrial end-use category, it is assumed that the full remainder can be allocated to the AFF sector.

Census data are used to estimate the number of AFF employees at the ZIP code level and ultimately the community scale. Census *Business Patterns* data provide counts of establishments at the ZIP code level, by North American Industry Classification System (NAICS) code, within one of nine broad size ranges: 1-4 employees; 5-9 employees; 10-19 employees; 20-49 employees; 50-99 employees; 100-249 employees; 250-499 employees; 500-999 employees; and 1000+ employees. In addition, Census also releases total counts of employees by ZIP code in aggregate, without distinguishing industry type. Using these two datasets, total number of employees by ZIP code and industry type are estimated through an iterative computation process in which the median number of employees for each size range is multiplied by the number of corresponding establishments within each ZIP code and scaled so that the resulting number of employees equals state totals. Typically, the process results in downward adjusted medians, indicating that—on average—the number of employees within a given establishment is slightly less than the median of its size range.

Census ZIP code-to-place mapping data (U.S. Census Bureau, 2010) are used to sum the total number of estimated employees within each Census place. Since ZIP codes do not align evenly with place boundaries, data on the share of total ZIP code land area within each ZIP-to-place relationship are used to allocate and sum employee totals by industry type for all census places, with the assumption that land area serves as a viable proxy for the distribution of AFF establishments and employees. It is important to note that some ZIP codes containing AFF establishments and their associated employees may partially or completely fall outside of any census place boundary. Energy consumption associated with these areas is still calculated, however these estimates are kept separate in order to avoid over-estimating community-specific consumption.

During the computation process, estimated number of employees are broken out into AFF and non-AFF sector totals based on NAICS code. Estimates corresponding to NAICS codes falling outside of the AFF sector are filtered out and retained for other sub-sector estimates (see accompanying appendices).

The below equation represents the calculation method utilized to estimate agriculture, forestry, and fishing (AFF) sector electricity consumption at the community scale.

Equation 21

$$\text{Community-scale AFF consumption} = (\text{aggregate state sales}_{\text{industrial}} - \text{aggregate state sales}_{non-AFF}) \times \left(\frac{\text{total community employees}_{\text{AFF}}}{\text{total state employees}_{\text{AFF}}}\right)$$

Table B*31. Equation 21 Data Elements*

Data element	Description	Source	Units
Community-scale AFF consumption	All electricity consumption within community boundary for a single year for all agriculture, forestry, and fishing establishments	Calculated	MWh
Aggregate state sales industrial	Amount of electricity sold to industrial establishments within entire state (includes industrial end-users such as construction and mining as well as agriculture)	(EIA, 2017d)	MWh
Aggregate state sales non-AFF	Estimated amount of electricity sold to all non-agriculture, forestry, and fishing industrial end-users within entire state	Computed value; (EIA, 2017d); (U.S. Census Bureau, 2015)	MWh
Total community employees AFF	Estimated number of agriculture, forestry, and fishing sector employees within the community	Computed value; (U.S. Census Bureau, 2017)	employees
Total state employees AFF	Estimated number of agriculture, forestry, and fishing sector employees within the state	Computed value; (U.S. Census Bureau, 2017)	employees

Methodology Assumptions and Potential Improvement

General assumptions

- Categories of employees identified by NAICS classification codes in Census data and used to produce employee estimates align with categories included within the EIA industrial end-use category
- After accounting for the share comprised by manufacturing, construction, and mining-quarrying, and oil and gas activities, remaining electricity consumption from the industrial end-use sector in EIA state sales data may be allocated to AFF activities

Spatial assumptions

- The distribution of AFF electricity consumption within a state is proportionally related to the distribution of AFF sector establishments and employees
- The distribution of AFF establishments and associated employees within a ZIP code territory is proportionally related to land area distribution.

- Relative industrial consumption patterns by subtype (e.g. the share of fuel consumed by manufacturing vs. construction), derived from BEA's Input-Output data at the national level, are applicable as allocation factors at a state level

Temporal assumptions

- Relative consumption patterns by the AFF sector and other industrial subtypes (e.g. the share of fuel consumed by AFF, manufacturing, or construction), derived from BEA's 2007 Input-Output tables, serve as a viable proxy for relative consumption patterns in subsequent years

Potential Improvement

The method described above accounts for differences in energy consumption patterns by AFF and other industry subtypes by establishing allocation factors using BEA data tables. This allows for estimates that are more reflective of the fuel requirements of different industries, however these categories remain quite broad, and a method that incorporates more granular subtypes with different energy needs – such as logging and crop production – would be more desirable.

In addition, while the approach described above relies on number of employees as a disaggregation factor, other potential factors exist which may have an even stronger proportional relationship to energy consumption, such as economic output (either as a dollar value or physical units of production). However, a key reason for the use of employee data in this iteration is that it was readily available through U.S. Census estimates. Community scale information on AFF economic output, by contrast, is typically proprietary in the United States and thus is not an open data source.

Table B32. Emission Factors:

Fuel Type	kg CO_2 per scf	g CH_4 per scf	g N_2O per scf	Source
Natural Gas	0.05444	0.00103	0.00010	(EPA, 2015)

Fuel Type	kg CO_2 per gallon	g CH_4 per gallon	g N_2O per gallon	Source
Distillate Fuel Oil[16]	10.45	0.42	0.08	(EPA, 2015)
Kerosene	10.15	0.41	0.08	(EPA, 2015)

Grid Electricity	See Appendix E

Sources: EPA 2015 (natural gas, distillate fuel oil); EPA 2018 (grid electricity)

References:

Bureau of Economic Analysis (BEA). (2014). Input-Output Accounts Data: Use Tables – 2007. Release date: 11/13/14. Retrieved from: https://www.bea.gov/industry/io_annual.htm

Provides estimates on the flow of commodities between industries, used to estimate the relative fuel consumption patterns of different industrial categories (e.g. manufacturing, construction, agriculture)

EIA. (2017a). Natural Gas Consumption by End Use. Release date: 12/29/2017. Retrieved from: https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm

Provides state-level natural gas sales totals by end-use category, which are disaggregated to the community-scale.

EIA. (2017b). Sales of Distillate Fuel Oil by End Use. Release date: 12/19/2017. Retrieved from: https://www.eia.gov/dnav/pet/pet_cons_821dst_dcu_nus_a.htm

Provides state-level fuel oil sales totals by end-use category, which are disaggregated to the community scale.

EIA. (2017c). Sales of Kerosene by End Use. Release date: 12/19/2017. Retrieved from: https://www.eia.gov/dnav/pet/pet_cons_821ker_dcu_nus_a.htm

Provides state-level kerosene sales totals by end-use category, which are disaggregated to the community scale.

EIA. (2017d). Form EIA-861 detailed data files. Sales to Ultimate Customers. Release date: 11/6/17. Retrieved from: https://www.eia.gov/electricity/data/eia861/

Provides state-level electricity sales totals by end-use category, which are disaggregated to the community-scale.

EPA. (2015). Emission Factors for Greenhouse Gas Inventories. EPA Center for Corporate Climate Leadership. Last modified: 11/19/15. Retrieved from: https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

Provides U.S.-specific emission factors for the combustion of fuels included in the methodology.

EPA. (2018). Emissions & Generation Resource Integrated Database (eGRID). eGRID 2016. Released: 2/15/2018. Retrieved from: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Provides U.S. grid region-specific emission factors for electricity consumption.

U.S. Census Bureau. (2015). 2012 Economic Census of the United States. Release date: 6/16/15. Retrieved from: https://www.census.gov/programs-surveys/economic-census/data/tables.2012.html

Provides estimates on the average annual electricity expenditures of various industries, used to estimate the relative consumption patterns of different industrial categories (e.g. manufacturing, construction, agriculture)

U.S. Census Bureau. (2017). CBP Datasets - 2015: Complete ZIP Code Industry Detail File; Complete ZIP Code Totals File. Released 4/20/17. Retrieved from: https://www.census.gov/data/datasets/2015/econ/cbp/2015-cbp.html

Used to estimate the number of commercial sector employees, by establishment size, at the ZIP code level.

Fugitive Emissions

As of yet, computations have not been completed to estimate community scale activity data for the fugitive emissions sector in the U.S. This gap in data coverage stems largely from two related issue areas: 1) issues regarding scope and emissions allocation and 2) issues regarding activity data and disaggregation. These issues are elaborated upon below, followed by a brief discussion of potential interim calculation methodologies for the sector.

Issues Regarding Scope and Emissions Allocation

In the U.S., for the year 2015, methane emissions from natural gas systems were estimated at 162.4 MMT CO_2e, or approximately 3% of total energy sector emissions (EPA, 2017a). Methane emissions from petroleum systems were estimated at 39.9 MMT CO_2e, or approximately 0.72% of total energy sector emissions (EPA, 2017a). These estimates exhibit an uncertainty range of between -19% (lower bound) and +30% (upper bound) for natural gas systems and between -24% (lower bound) and +149% (upper bound) for petroleum systems (EPA, 2017b) (EPA, 2017c).

Demonstrating the complexity of calculating emissions from the sector, for emissions from natural gas systems alone, the EPA has developed over 80 emission factors to characterize emissions from various system segments (EPA, 2017d). Broadly, EPA, IPCC, and other bodies divide out sector emissions and their corresponding emission factors into operating stages of oil and gas systems. These stages, along with the share of total natural gas methane emissions they are estimated to make up in the U.S., are detailed in Table B33.

Table B33. U.S. 2015 Natural Gas System Methane Emissions by Operating Stage

System Operating Stage	Description	Estimated 2015 Emissions (MMT CO2 Eq) for U.S.	Share of total
Production	Emissions occurring during the withdrawal of raw gas from underground wells and transfer to transmission pipelines (e.g. gathering stations, pneumatic controllers, gas engines, liquids unloading, and offshore platform).	106.6	65.64%
Processing	Emissions occurring during the transformation of natural gas to “pipeline quality,” (e.g. from compressors).	11.1	6.83%
Transmission and Storage	Emissions occurring during the transportation of natural gas via high pressure, large diameter pipelines (e.g. from compressor stations and venting from pneumatic controllers) and storage tanks.	33.7	20.75%
Distribution	Emissions occurring during the distribution of natural gas from “city gate” stations to individual end-users via underground mains and service lines.	11	6.77%

Source: U.S. Environmental Protection Agency (EPA). (2017). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2015. April 2017. Table 3-51. https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf

Current CRF guidance advises the calculation of community-scale oil and gas system fugitive emissions for scope 1 only, i.e. only those occurring within the defined community boundary. However, as included in Table B33, the majority of the sector's emission occur during production and transmission operating stages, which may often fall outside of community boundaries. Assuming that for majority of communities the only relevant activity data will stem from the distribution operating stage (which comprises just 7% of total sector emissions), it follows that only a fraction of total sector emission would be captured within a Scope 1 computation.

To establish a methodology that produces meaningful community-scale activity data, more research will be needed on this issue. Specifically, more investigation is needed to determine to what extent upstream operating stages (e.g. production and transmission) take place within community boundaries in the U.S. If it is indeed found that the majority of such activities do not occur within community boundaries, then either a) the Data Portal research team may want to consider a Scope 1 approach that considers life-cycle emissions related to activities outside of the community boundary or b) the published estimates should include a disclaimer indicating that the activity data do not capture the majority of oil and gas system emissions.

Issues Regarding Activity Data and Disaggregation

Activity data used to calculate national-level natural gas system emissions may include (by relevant operating stage): statistics on gas production, number of wells, system throughput, number of various station types, number of various compressor types, and miles of various kinds of pipe (e.g. cast iron, steel, plastic). Table B34 outlines example activity data points used by EPA to calculate national-level U.S. emissions. The table is meant to be illustrative only, as actual EPA calculation methods involve many additional data points and emission factor calculation methodologies not mentioned herein.

Table B34. Example U.S. Activity Data Points

System Operating Stage	Activity Data Point	Source	Spatial Resolution
Production	Number of wells	(DrillingInfo, 2017)	Not specified
	Gathering and boosting stations	(Marchese, et al. 2015)	State
	Total withdrawals and production (MMcf)	(EIA, 2017)	State
Transmission and Storage	Compressor stations	(EPA, 2017a)	State
	Pipeline mileage	(PHMSA, 2017a)	State
Distribution	City gate stations	(EPA, 2017e)	State

	Pipeline mileage	(PHMSA, 2017b)	State
	Customer meters	(EIA, 2017b)	State

A critical issue in calculating meaningful community-scale oil and gas system fugitive emissions for the U.S. arises from the fact that activity data are not disaggregated beyond regional levels (e.g. individual states) and proxy factors that may be used to further disaggregate data have not been determined. As included in Table B34 above, relevant datasets from EIA, EPA, and PHMSA are available only at the resolution of U.S. states.

More research will be needed to determine what – if any – supplementary data may be available to disaggregate data on pipeline mileage, wells, compressor stations and other infrastructure to the community scale and apply corresponding emission factors. In addressing this issue in the United States and in other country contexts, the Data Portal research team will need to look to industry and government agency experts to inform decision-making.

Possible Solutions

In light of the issues highlighted above, the following interim solutions may be taken to produce community-scale estimates until additional research can be done:

a) Disaggregate national level estimates to the community-scale
    - The EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks estimates oil and natural gas system methane emissions on a national level. These national totals may be disaggregated to communities using rough disaggregation factors such as population or GDP.

b) Estimate emissions using consumption as a proxy for distribution throughput
    - The IPCC publishes default, tier 1 emission factors for oil and gas throughput – for example, the amount of natural gas distributed in terms of Gg per 10^6 m^3 of utility sales. Notwithstanding the uncertainty associated with using the tier 1 method (IPCC lists an upper bound uncertainty of as high as +500%) (IPCC, 2006), this may represent a viable interim approach for emissions, particularly since natural gas consumption will be already calculated for communities using the methodologies in the accompanying appendices.

References:

Drillinginfo. (2017). DI Desktop® Download. DrillingInfo, Inc.

EIA. (2017a). Natural Gas Gross Withdrawals and Production: Marketed Production. Energy Information Administration, U.S. Department of Energy, Washington, DC. Retrieved from: https://www.eia.gov/dnav/ng/ng_prod_sum_dc_NUS_mmcf_a.htm

EIA. (2017b). Number of Natural Gas Consumers. Energy Information Administration, U.S. Department of Energy, Washington, DC.

IPCC. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Table 4.2.4 Tier 1 Emission Factors for Fugitive Emissions (Including Venting and Flaring) from Oil and Gas Operations in Developed Countries.

Marchese, et al. (2015). "Methane Emissions from United States Natural Gas Gathering and Processing." Environmental Science and Technology, Vol. 49 10718−10727.

PHMSA. (2017a) "Annual Report Mileage for Natural Gas Transmission and Gathering Systems." Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation, Washington, DC.

PHMSA. (2017b) "Annual Report Mileage for Natural Gas Distribution Systems." Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation, Washington, DC.

U.S. Environmental Protection Agency (EPA). (2017a). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2015. April 2017. Table 3-1: CO2, CH4, and N2O Emissions from Energy (MMT CO2 Eq.). https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf

U.S. Environmental Protection Agency (EPA). (2017b). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2015. April 2017. Table 3-54. https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf

U.S. Environmental Protection Agency (EPA). (2017c). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2015. April 2017. Table 3-40. https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf

U.S. Environmental Protection Agency (EPA). (2017d). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2015. April 2017. Section 3.7 Natural Gas Systems: Methodology. https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf

U.S. Environmental Protection Agency (EPA). (2017e). Greenhouse Gas Reporting Program- Subpart W – Petroleum and Natural Gas Systems. Environmental Protection Agency.

U.S. Environmental Protection Agency (EPA). (2017f). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2015. April 2017. Table 3-51. https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf

Transportation and Mobile Energy Sector

This section details the calculation approaches and data sources for producing community-level activity data and emission factors for the transportation and mobile energy sector. For the United States, the data estimation methodologies cover the following subsectors, initially for the year 2015:

Table B35. Transportation and Mobile Energy Sector Coverage

Transportation and Mobile Energy Sector	
On-road	Estimated
Rail	Not Currently Estimated
Waterborne navigation	Not Currently Estimated
Aviation	Estimated
Off-road	Estimated

On-Road

Subsector Summary

GHG emissions within the On-Road subsector result from the consumption of fuel for on-road vehicles such as passenger cars, light trucks, motorcycles, buses, single-unit trucks, and combination trucks. This methodology describes the process for generating estimates of total fuel consumption comprised by these vehicle types within the community boundary (scope 1) including gasoline, diesel, and alternative fuels. This subsector methodology does not cover grid electricity consumed for on-road vehicles used within the community boundary (scope 2), which is instead included in the Stationary Energy sector.

Inclusions

For the United States, based on available data and methods, estimates of activity data produced include:

- **Gasoline** and **diesel fuel** consumption for private and commercial and publicly owned passenger cars, light trucks, motorcycles, buses, single-unit trucks, and combination trucks within a community boundary.
- **Compressed natural gas** (CNG), **ethanol – 85 percent** (E85), **hydrogen**, **liquefied natural gas** (LNG), and **liquefied petroleum gas** (LPG) consumption for light-, medium-, and heavy-duty vehicles, and buses for four types of fleets: federal government, state governments, transit agencies, and fuel providers within a community boundary.

Exclusions

Due to lack of data, this methodology does not include:

- **Electricity** consumption from on-road vehicles (instead this electricity consumption is included in the Stationary Energy sector)
- **Compressed natural gas** (CNG), **ethanol – 85 percent** (E85), **liquefied natural gas** (LNG), and **liquefied petroleum gas** (LPG) consumption for all vehicle types that are not part of a federal government, state government, transit agency, or fuel provider fleet types.

Activity Data Coverage

Table B36 includes the emissions sources covered by this methodology.

Table B36 – Allocated activity data, units, and emission sources

Emissions Source	Definition	Units	Scope
Private and commercial passenger car gasoline	The amount of gasoline consumed for a single year by private and commercial passenger cars in a community boundary	Gallons	Scope 1
Publicly owned passenger car gasoline	The amount of gasoline consumed for a single year by publicly owned passenger cars in a community boundary	Gallons	Scope 1
Private and commercial light trucks gasoline	The amount of gasoline consumed for a single year by private and commercial light trucks in a community boundary	Gallons	Scope 1
Publicly owned light trucks gasoline	The amount of gasoline consumed for a single year by publicly owned light trucks in a community boundary	Gallons	Scope 1
Private and commercial motorcycles gasoline	The amount of gasoline consumed for a single year by private and commercial motorcycles in a community boundary	Gallons	Scope 1
Publicly owned motorcycles gasoline	The amount of gasoline consumed for a single year by publicly owned motorcycles in a community boundary	Gallons	Scope 1
Private and commercial buses diesel	The amount of diesel consumed for a single year by private and commercial buses in a community boundary	Gallons	Scope 1
Publicly owned buses diesel	The amount of diesel consumed for a single year by publicly owned buses in a community boundary	Gallons	Scope 1
Private and commercial single-unit trucks diesel	The amount of diesel consumed for a single year by private and commercial single-unit trucks in a community boundary	Gallons	Scope 1
Publicly owned single-unit trucks diesel	The amount of diesel consumed for a single year by publicly owned single-unit trucks in a community boundary	Gallons	Scope 1
Private and commercial combination trucks diesel	The amount of diesel consumed for a single year by private and commercial combination trucks in a community boundary	Gallons	Scope 1
Publicly owned combination trucks diesel	The amount of diesel consumed for a single year by publicly owned combination trucks in a community boundary	Gallons	Scope 1

Allocation Methodology

Estimating community-level fuel consumption by vehicle type involves a complex array of variables, the most vital of which include:

- vehicle fuel economy by type
- roadway length and type
- traffic intensity by roadway type and region, and
- number and types of vehicles registered for private and commercial uses.

Accounting for these factors using a variety of public and proprietary datasets and spatial mapping techniques, the U.S. Department of Energy (DOE) developed a methodology for producing estimates of community-level vehicle fuel and miles traveled for the vintage year of 2013. These estimates are housed within DOE's State and Local Energy Data (SLED) tool (U.S. DOE 2015). The SLED data cover virtually all U.S. communities; however, they are not by default at the end-use resolution required for a community-scale inventory. For this methodology, the SLED estimates are used as a key disaggregation factor and are combined with state-level fuel sales data, roadway information, vehicle registration data, and other factors to produce estimates at the required resolution in terms of end-use categories.

Gasoline and Diesel Fuel Consumption

Gasoline and diesel fuel consumption for on-road vehicles is calculated using:

a) state-level on-road vehicle fuel consumption data from the Federal Highway Administration (FHWA) as top-down input data;
b) community-level gasoline consumption, diesel consumption, and vehicle miles traveled (VMT) data from DOE's SLED tool as disaggregation factors to scale state-level fuel consumption to the community level; and
c) supplementary datasets from FHWA and other sources described below used to further disaggregate community level fuel consumption into constituent end-use sectors (e.g., private, commercial) and vehicle types.

In certain states and regions, a significant share of on-road vehicle fuel consumption may occur along freight corridors, interstate highways, or through otherwise unincorporated zones that cannot be attributed to the Scope 1 boundary of any specific community. Rather than directly assess the share of on-road fuel consumption taking place outside of community boundaries due to these factors, this methodology infers the amount already accounted for in the 2013 SLED estimates.

As an initial step, it was necessary to estimate the extent of non-community fuel consumption. Determining the non-community consumption already factored out of DOE's SLED data are calculated through the difference between the 2013 SLED estimates by state and the FHWA state fuel consumption totals from the same year. Since the 2013 SLED estimates are normalized to aggregate up to FHWA totals, any difference between the sum of the SLED community estimates and the state totals is assumed to be the amount of non-community fuel consumption. In some states, the remainder is zero, indicating that all on-road fuel consumption within the state boundary occurs within a community boundary. However, in other, particularly less densely populated states, the remainder is nearly equal to or larger than the amount which can be attributed to communities. For each state, the share of community versus non-community consumption is converted to a percentage and used to factor out non-community fuel consumption from the more recent vintage FHWA state totals for the purposes of this methodology.

Equation 22 provides the method for calculating this allocation factor.

Equation 22

$$Community\ allocation\ factor_{fuel\ type,\ state} = \frac{\sum 2013\ SLED\ community\ fuel\ consumption_{fuel\ type,\ state}}{2013\ FHWA\ fuel\ consumption_{fuel\ type,\ state}}$$

Table B37. *Equation 22 Data Elements*

Data element	Definition	Units	Source
Community allocation factor $_{fuel\ type,\ state}$	Proportion of total state on-road gasoline or diesel consumption that can be allocated to community boundaries	Unitless	Calculated
2013 SLED community fuel consumption	Estimated community level gasoline or diesel consumption by all on-road vehicles, summed by state	Gallons	U.S. DOE, 2015
2013 FHWA fuel consumption	Consumption of gasoline or diesel by all on-road vehicles by state	Gallons	FHWA, 2014

After accounting for the share of fuel consumption occurring outside of community boundaries, the remaining totals for gasoline and diesel consumption at the state level are disaggregated to the community level using the proportion of community fuel consumption relative to the state totals, per the 2013 SLED values. It is assumed the 2013 SLED data have remained consistent over time.

Equation 23 provides the approach used to disaggregate state level fuel consumption to the community scale.

Equation 23

$$Community\ fuel\ consumption_{fuel\ type} = total\ fuel\ consumption_{fuel\ type,\ state} \times community\ allocation\ factor_{fuel\ type,\ state} \times \frac{SLED\ community\ fuel\ consumption_{fuel\ type}}{SLED\ state\ fuel\ consumption_{fuel\ type}}$$

Table B38. *Equation 23 Data Elements*

Data element	Definition	Units	Source
Community fuel consumption $_{fuel\ type}$	Consumption of gasoline or diesel by all on-road vehicles within the community boundary	Gallons	Calculated
Total fuel consumption $_{fuel\ type,\ state}$	Consumption of gasoline or diesel by all on-road vehicles for the state	Gallons	FHWA, 2017
Community allocation factor $_{fuel\ type,\ state}$	Proportion of total state on-road fuel consumption that can be allocated to community boundaries	unitless	Equation 22

SLED community fuel consumption $_{\text{fuel type}}$	2013 estimate of consumption of gasoline or diesel by all on-road vehicles for the community boundary	Gallons	U.S. DOE, 2015
SLED state fuel consumption $_{\text{fuel type}}$	Sum of all estimated gasoline or diesel consumption by on-road vehicles for all communities in a given state	Gallons	U.S. DOE, 2015

The calculations result in community-scale estimates of gasoline and diesel consumption from on-road vehicles in aggregate. These estimates are then further disaggregated to produce estimates at the necessary sectoral and vehicle type resolution (e.g., privately-owned passenger cars, public light-duty trucks). This is done using the 2013 NREL SLED estimates of total VMT at the community level and disaggregating VMT by vehicle type based on supplementary FHWA datasets.

The supplementary datasets contain estimates of the average proportions of 1) roadway types and 2) various vehicle types as a share of total traffic for each roadway type. These proportions are at the state level and differ based on the two broad categories of either "urban" and "rural" areas. A simplifying assumption is made that communities with a population greater than or equal to 2,500 contain roadway and vehicle type proportions corresponding to the "urban" FHWA category within a given state, whereas communities with a population below this number contain the relative roadway and vehicle type proportions corresponding to the "rural" category.

Equation 24 provides how VMT is disaggregated by vehicle type.

Equation 24

$$\text{VMT}_{vehicle\ type} = \sum_{vehicle\ type} \left(Community\ VMT \times Roadway\ length\ proportion_{roadway\ type} \times Vehcile\ use\ proportion_{vehicle\ type,\ roadway\ type}\right)$$

Table B39. *Equation 24 Data Elements*

Data element	Definition	Units	Source
VMT $_{\text{vehicle type}}$	Vehicle miles traveled, by vehicle type, attributed to the community.	VMT	Calculated
Vehicle use proportion	Average proportion of vehicle traffic comprised of each vehicle type (motorcycles, passenger cars, light trucks, buses, single-unit trucks, combination trucks) for each roadway type (interstate, arterial, or "other" local and collector roadways)	unitless	FHWA, 2017
Roadway length proportion	Average proportion of total roadways comprised of each roadway type (interstate, arterial, or "other" local and collector roadways)	unitless	FHWA, 2017

Community VMT	Vehicle miles traveled attributed to the community in a single year	VMT	U.S. DOE, 2015

With aggregate community VMT broken out by vehicle type, fuel consumption for a given vehicle type is calculated by first establishing a fraction representing the vehicle type's fuel consumption relative to all vehicles consuming the same type of fuel (e.g. gasoline or diesel). The calculation of this fraction is shown in the parenthetical portion of Equation 25. The fraction is based on the estimated VMT of each vehicle type for the community converted to gallons of fuel consumption using each vehicle type's relative efficiencies in miles per gallon (MPG). Lastly, each vehicle type's fuel consumption fraction is multiplied by the total community fuel consumption to estimate fuel consumption for that vehicle type.

Equation 25 provides the process for calculating fuel consumption by vehicle type.

Equation 25

$$\text{Community fuel consumption}_{vehicle\ type} = \text{Community fuel consumption} \times \left(\frac{VMT_{vehicle\ type}}{mpg_{vehicle\ type}} \div \sum_{vehicle\ type} \frac{VMT}{MPG} \right)$$

Table B40. *Equation 25 data elements*

Data element	**Definition**	**Units**	**Source**
Community fuel consumption $_{\text{vehicle type}}$	Consumption of on-road gasoline or diesel, by vehicle type, attributed to the community	Gallons	Calculated
Community fuel consumption	Consumption of on-road gasoline or diesel attributed to the community in a single year	Gallons	Equation 23
VMT $_{\text{vehicle type}}$	Vehicle miles traveled by vehicle type attributed to the community in a single year	VMT	Equation 24
MPG $_{\text{vehicle type}}$	Average national vehicle fuel economy by vehicle type in 2015	mpg	FHWA, 2017

As a final step, fuel consumption by vehicle type is broken out by fleet type (private and commercial or public) using supplementary data from FHWA on total vehicle registrations by fleet type at the state level. It is assumed that the relative share of public and private ownership by vehicle type at the state level is consistent at the community scale as well, because no additional data are available on share of ownership below the state level.

Equation 26

$$\text{Community gasoline consumption}_{vehicle\ type,\ fleet\ type} = \text{Community fuel consumption}_{vehicle\ type} \times \frac{\text{State vehicle registrations}_{vehicle\ type,\ fleet\ type}}{\text{Total state vehicle registrations}_{vehicle\ type}}$$

Table B41. *Equation 26 data elements*

Data element	Definition	Units	Source
Community gasoline consumption $_{\text{vehicle type, fleet type}}$	Consumption of on-road gasoline or diesel, by vehicle type and fleet type, attributed to the community	Gallons	Calculated
Community fuel consumption $_{\text{vehicle type}}$	Consumption of on-road gasoline or diesel, by vehicle type, attributed to the community in a single year	Gallons	Equation 25
State vehicle registrations $_{\text{vehicle type, fleet type}}$	State motor vehicle registration numbers for a given vehicle type and fleet type (private and commercial or publicly owned) in a single year	Vehicles	FHWA, 2017
Total state vehicle registrations $_{\text{vehicle type}}$	Total state motor vehicle registration numbers for a given vehicle type	Vehicles	FHWA, 2017

Methodology Assumptions, Limitations, and Potential Improvement

General assumptions:

- Gasoline consumption is limited to fuel consumption by passenger cars, light trucks, and motorcycles; while a small share of these vehicle types may in fact have diesel-fueled engines, without precise data, the share is assumed de minimis in the current iteration of this methodology.
- Diesel consumption is limited to buses, single-unit trucks, and combination trucks; while a small share of these vehicle types may in fact have gasoline-fueled engines, without precise data, the share is assumed de minimis in the current iteration of this methodology.
- Gasoline and diesel sales and consumption for equipment other than vehicle transportation is assumed negligible relative to vehicle transportation but assumed consumed within the same spatial and temporal boundary.

Spatial Assumptions:

- Relative shares of vehicle fleet types (e.g. private or public) at the state level apply evenly across all communities within a given state;
- Relative shares of roadway types for urban or rural areas at the state level apply evenly across all communities within a given state;
- Relative shares of traffic comprised by various vehicle types by roadway type at the state level apply evenly across all communities within a given state;
- The distribution of state level of on-road fuel consumption occurring within community boundaries is proportionally related to relative patterns of consumption previously estimated in DOE's SLED tool
- Fuel sales in each state is equal to fuel consumption within the same state.

Temporal assumptions

- 2013 estimates of community scale fuel consumption and VMT from DOE's SLED tool serve as viable proxy factors for relative consumption patterns in subsequent data years.
- Fuel is consumed within the same year it is sold.

Vehicle type reconciliation assumptions

This methodology also relies on assumptions on how to assign vehicle types and road types to join different datasets. The vehicle type categorization for the fuel economy data is different than the categorizations used thus far. This methodology assumes that "light duty vehicles – short wheelbase" is equivalent to the passenger cars category and that "light duty vehicles – long wheelbase" is equivalent to the light trucks category.

Table B42 and Table B43 include the categorization assumptions made between other data sources as well.

Table B42 – Vehicle Type Reconciliation

FHWA State Motor Vehicle Registrations vehicle type categories	FHWA Distribution of Annual Distance Traveled vehicle type categories
Motorcycles	Motorcycles
Automobiles	Passenger cars
	Light trucks
Buses	Buses
Trucks	Single-unit trucks
	Combination trucks

Table B43 – Functional System Reconciliation

Distribution of Annual Distance Traveled functional system categories	Public Road Length functional system categories
Interstate systems	Interstate
	Other freeways and expressways
Other arterials	Other principal arterial
	Minor arterial
Other	Major collector
	Minor collector
	Local

Potential Improvement:

As stated above this methodology assumes that gasoline is consumed solely by passenger cars, light trucks, and motorcycles, while diesel is consumed solely by buses, single-unit trucks, and combination trucks. While this is the case for the majority of vehicle fleets in the U.S., future iterations of this methodology will aim to more accurately reflect nuances in fuels used by various vehicle types.

To disaggregate VMT by vehicle type, this methodology assumes that average shares of traffic comprised by various vehicle types along different categories of roadways at the state level may be evenly applied across communities throughout the state. Future iterations of this methodology will aim to more accurately reflect the relative differences in roadway and vehicle types at the intra-state level as more refined data becomes available.

Emission Factors:

Presented below are emission factors from the U.S. EPA's Center for Corporate Climate Leadership (EPA, 2015) which are U.S.-specific and may be used in combination with the activity data points estimated in the above methodology.

Table B44. Transportation Emission Factors

Fuel Type / Vehicle Type	CO_2 Factor (kg / gallon)	CH_4 Factor (g / mile)	N_2O Factor (g / mile)
Gasoline Passenger Cars	8.78	0.0173	0.0036
Gasoline Motorcycles	8.78	0.0672	0.0069
Gasoline Light Trucks	8.78	0.0163	0.0066
Gasoline Heavy-duty Vehicles	8.78	0.0333	0.0134
Diesel Medium and Heavy-duty Vehicles	10.21	0.0051	0.0048

References:

The SLED data include VMT and gasoline and diesel fuel consumption estimates for each community in the United States.

EPA. (2015). Emission Factors for Greenhouse Gas Inventories. EPA Center for Corporate Climate Leadership. Last modified: 11/19/15. Retrieved from: https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

Energy Information Administration. (2017b). "Sales of Distillate Fuel Oil by End Use." Retrieved from https://www.eia.gov/petroleum/data.php#consumption

This dataset provides annual distillate fuel oil sales, including diesel sales, by end use, including on-road uses.

Federal Highway Administration. (2017). "Highway Statistics 2015." Retrieved from https://www.fhwa.dot.gov/policyinformation/statistics/2015/

The Highway Statistics Series brings together data collected from federal, state, and local agencies relating to highway transportation in twelve major areas, including highway travel, motor fuel, and performance indicators.

U.S. DOE (Department of Energy). 2015. (Database). *State and Local Energy Data*. https://www.eere.energy.gov/sled/#/

Rail

Subsector Summary

GHG emissions within the Rail subsector result from the consumption of fuel and electricity for rail transportation. The Rail subsector includes scope 1 emissions (from fuel combustion within the community boundary) and scope 2 emissions (from consumption of grid-supplied energy) from rail systems that transport people and goods. These systems are typically powered by a locomotive, through the combustion of diesel or electricity.

Available Data

In the United States, there are some data sources that relate to rail activity and energy consumption, as included in Table B45.

Table B45. Allocated activity data, units, and emission sources

Activity Data	Definition	Units	Source
Diesel fuel consumption for all transit rail systems	Consumption of diesel fuel by public transit rail systems attributed to the community	Gallons	FTA, 2016
Bio-diesel fuel consumption for all rail systems	Consumption of bio-diesel fuel by public transit rail systems attributed to the community in a single year	Gallons	FTA, 2016
National revenue ton-miles	Total Class I railroad revenue ton-miles attributed to the United States in a single year	Billion ton-miles	ORNL, 2017
Miles of rail	Miles of rail in each county and nationally, by railroad owner, in a single year	miles	BTS, 2017
Grid-supplied electricity consumption for all rail systems	Consumption of electricity by public transit rail systems attributed to the community in the year 2015	MWh	FTA, 2016

Methodological Issues

Data Gaps

While there are many data elements that could contribute to an activity data estimate, issues with data quality and completeness prohibit from making rigorous estimates of activity data for each U.S. city. Developing a complete methodology for the Rail subsector would require reconciling the many different forms in which rail travel occurs in the United States – including freight, light rail, commuter, and long-distance rail. These forms would potentially require a unique allocation methodology for each type. Complicating this, many of these rail types are operated by different entities, meaning that any available data would have to be collected and cleaned from many sources. This problem is most relevant in the case of regional or metro-area rail systems.

Attribution Difficulties

While transboundary attribution can be an issue for all estimates within the Transport and Waste sectors, this problem is especially present in the Rail subsector. In the case of a passenger train with multiple stops, it can be difficult to determine how to fairly allocate the fuel consumption of the train to each community at which it stops, in addition to each municipality that the train passes through along the way. It may be possible to develop a methodology by tracking the origin and destination of all passengers on all forms of rail, but it has so far been unsuccessful in finding the granularity of data necessary for such an approach.

References:

Association of American Railroads. (2017). "Class I Railroad Statistics." Retrieved from https://www.aar.org/Documents/Railroad-Statistics.pdf

This source provides statistics on Class I Railroads and provide the working definition of Class I Railroad from this source.

Bureau of Transportation Statistics. (2017). "Railroad Lines." Retrieved from http://osav-usdot.opendata.arcgis.com/datasets?keyword=Rail

The Railroad Lines dataset provides the mileage of rail in each county, by the railroad owner for each segment.

Environmental Protection Agency. (2015). "Center for Corporate Climate Leadership Emission Factors Hub." Retrieved from https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

EPA provides a set of default emission factors for greenhouse has reporting.

Federal Transit Administration. (2018). "National Transit Database (NTD) Glossary." Retrieved from https://www.transit.dot.gov/ntd/national-transit-database-ntd-glossary

This glossary provides definitions for each transit railway system.

Federal Transit Administration. (2016). "2015 Fuel and Energy." Retrieved from https://www.transit.dot.gov/ntd/data-product/2015-fuel-and-energy

The 2015 Fuel and Energy dataset provides data on fuel consumption, by type of fuel, for each transit agency, by type of rail system.

Oak Ridge National Laboratory. (2017). "Transportation Energy Data Book: Edition 36 – Class I Railroad Freight Systems in the United States Ranked by Revenue Ton-Miles, 2015" Retrieved from http://cta.ornl.gov/data/index.shtml

Provides data on total revenue ton-miles traveled by each Class I railroad in a single year.

U.S. Census Bureau. (2017). "City and Town Population Totals: 2010-2016." Retrieved from https://www.census.gov/data/datasets/2016/demo/popest/total-cities-and-towns.html

The U.S. Census Bureau projects population estimates for cities and towns based on the 2010 census.

Waterborne Navigation

Subsector Summary

Within the Common Reporting Framework's reporting guidance, GHG emissions within the Waterborne Navigation subsector should comprise of the consumption of **fuel** and **electricity** for ships, ferries, and other boats operating within the community boundary, as well as vessels whose journeys originate or end at points within a community boundary but travel to destinations outside of the community.

Available Data

In the United States, there are some data sources that relate to waterborne navigation activity and energy consumption, as included in Table B46.

Table B46. U.S. Waterborne Navigation Data Sources

Data element	Definition	Units	Source
Ferry vessel census nautical miles traveled	Nautical miles traveled by each ferry within a single year	Nautical miles	BTS, 2016
Ferry vessels fuel mileage	Fuel mileage for each ferry	Nautical miles per gallon	BTS, 2016
Ferry vessel terminal segments served	For each terminal segment, identification of the vessel that first-most, second-most, and third-most serve that terminal segment in a single year	Number terminals	BTS, 2016
Ferry vessel segment miles	The number of nautical miles for each vessel segment	Nautical miles	BTS, 2016
Boat registrations by boat type and boat size	The number of recreational boats registered in each state, broken down by boat type and boat length, for a single year	Number boats	USCG, 2016
Public transit ferry energy consumption	Consumption of diesel, gasoline, and biodiesel by ferry services run by transit agencies	Gallons	FTA, 2016
Private and commercial boating gasoline consumption	Consumption of gasoline for private and commercial boating activities in each state for a single year	Thousand gallons	FHWA, 2016
Sales of distillate fuel oil for vessel bunkering	Sales of distillate fuel oil for commercial and private boats, including pleasure craft, fishing boats, tugboats, ocean-going vessels, and vessels operated by oil companies in each state for a single year	Thousand gallons	EIA, 2017
Sales of residual fuel oil for vessel bunkering	Sales of residual fuel oil for commercial and private boats, including pleasure craft, fishing boats, tugboats, ocean-going	Thousand gallons	EIA, 2017

	vessels, and vessels operated by oil companies in each state for a single year		
Water area	Total square meters of water area within a community boundary	Square meters	DOE, 2015

Methodological Issues & Data Gaps

While there are many data elements that could contribute to an activity data estimate, issues with data quality and completeness prohibit from making rigorous estimates of activity data for each U.S. city.

Ferry Activity Data

While it could be possible to use data from the Bureau of Transportation Statistics (BTS) through the National Census of Ferry Operators (NCFO) to determine the amount of fuel each vessel consumes, it is not possible to determine how often the vessel serves each segment, so allocating fuel consumption to each terminal and the community that terminal serves cannot be done accurately. The NCFO data are also missing data from a subset of ferry operators in the United States, and even among operators that responded to the census there are missing data. While the Federal Transit Administration (FTA) has energy consumption data for each transit agency, the activity data are associated with only the community for which each transit agency primarily serves. Data limitations prevent from allocating the activity data to each community

Private and Commercial Boating Activity Data

There is data for consumption of gasoline, distillate fuel oil, and residual fuel oil for waterborne navigation in each state. There are also state boat registration data and water area values for each community. However, there are different possible fuel types that could be used for a subset of registered boats and there was not sufficient data to determine the breakdown of gasoline consuming boats and diesel consuming boats. There was also not sufficient data to allocate the proportion of sales of distillate fuel and sales of residual fuel that should be allocated to in-boundary and domestic waterborne trips (i.e. what proportion of the fuel sales are going to ocean-going boats). Furthermore, there was not sufficient data to assess the water area in each community and determine the allocation of boats to different bodies of water and to determine which bodies of water may have a larger concentration of boats.

References:

Bureau of Transportation Statistics. (2016). “National Census of Ferry Operators.” Retrieved from https://www.bts.dot.gov/surveys/national-census-ferry-operators-ncfo/national-census-ferry-operators-ncfo

The biennial census of all ferry operators in the U.S. and its territories contains information on ferry routes, vessels, passengers and vehicles carried, funding sources, and more.

Energy Information Administration. (2017). “Petroleum & Other Liquids Consumption/Sales.” Retrieved from https://www.eia.gov/petroleum/data.php#consumption

This dataset provides annual sales data for liquid fuels, by state and end use, including distillate fuel oil and residual fuel oil.

Federal Highway Administration. (2016). "Highway Statistics 2015: Non-Highway Use of Gasoline." Retrieved from https://www.fhwa.dot.gov/policyinformation/statistics/2015/

The Highway Statistics Series brings together data collected from federal, state, and local agencies relating to highway transportation in twelve major areas, including highway travel, motor fuel, and performance indicators. This series also contains data on non-highway use of gasoline.

Federal Transit Administration. (2016). "2015 Fuel and Energy." Retrieved from https://www.transit.dot.gov/ntd/data-product/2015-fuel-and-energy

The 2015 Fuel and Energy dataset provides data on fuel consumption, by type of fuel, for each transit agency, by type of transit.

United States Coast Guard. (2016). "USCG Registered Boats." Retrieved from direct communications with USCG; summary available at http://www.uscgboating.org/statistics/accident_statistics.php

The dataset contains information about the number of registered recreational boats in each state, including the type of motor (if applicable), and the size of the boar.

Aviation

Subsector Summary

GHG emissions within the Aviation subsector result from fuel consumption for passenger and freight domestic air travel within a community boundary. The GHG emitting activity focused on in this subsector is fuel consumption (jet fuel and aviation gasoline) for domestic flights.

Inclusions

For the United States, based on available data and methods, activity data produced includes:

- **Jet Fuel** and **Aviation Gasoline** consumption from airborne trips by certificated U.S. air carriers and foreign carriers (passenger and freight)[17] based on payload data for domestic flights originating out of any airport located within the boundary of a designated community.

Exclusions

Due to lack of data, the activity data provided excludes:

- **Jet Fuel** and **Aviation Gasoline** consumption from airborne trips not originating at a designated domestic airport—e.g., privately-owned or municipal helicopters.
- **Jet Fuel** and **Aviation Gasoline** consumption from non-certificated air carriers.
- **Electricity** from airborne transportation.

Due to reporting framework guidelines in the GPC and CRF, the activity data provided excludes:

- **Flights that arrive or depart internationally**, which would fall into the category of scope 3 emissions.

Activity Data Coverage

Table B47 includes the community-scale activity data, and associated emission scope, for the Aviation subsector provided for the United States.

Table B47. Allocated activity data, units, and emission sources

Activity Data	Definition	Units	Emissions Scope
Jet fuel	The amount of jet fuel consumed for a single year from all airports located within the community boundary	Gallons	Scope 1
Aviation gasoline	The amount of aviation gasoline consumed for a single year from all airports located within the community boundary	Gallons	Scope 1

Allocation Methodology

Fuel Consumption

This methodology makes use of a top-down fuel consumption approach to allocate U.S. state-level annual fuel consumption data, by fuel type, to the city level. Used is a method that relies on flight origin-destination data to counts fuel consumption from half of flights arriving at a community and fuel consumption from half the flights departing a city. It is assumed that all the fuel consumed in the state represents the total of in-state travel and the fuel dispensed by domestic flights arriving at the community equals the fuel used for domestic flights departing from the city. Used are payload proportions for each domestic airport to disaggregate state-level jet fuel and aviation gasoline consumption to each airport. Payload serves as a proxy both for the amount of passengers and the amount freight that moves through each airport. The Bureau of Transportation Statistics defines payload as the "certificated takeoff weight of an aircraft, less the empty weight, less all justifiable aircraft equipment, and less the operating load (consisting of minimum fuel load, oil, flight crew, steward's supplies, etc.)" (BTS, 2017a).

This methodology allocates all local and domestic flight activity from an airport as scope 1 emissions to the community where that airport is located. Although some airports serve multiple communities and, in some circumstances, multiple states, allocating emissions to one source allows this methodology to disaggregate accurately and ensure that estimates will align with reported fuel sales and fuel consumption estimates at the state and national level.

Equation 27 and Equation 28 provide the method used to estimate community-level aviation fuel consumption.

Equation 27

$$\text{Community jet fuel consumption} = \text{State jet fuel consumption} \times \frac{\sum_{community\ airports} \text{Payload}}{\sum_{state\ airports} \text{Payload}}$$

Table B48. Data sources to estimate community jet fuel consumption

Data element	Definition	Units	Source
Community jet fuel consumption	Consumption of jet fuel allocated to the community	Million barrels	Calculated
State jet fuel consumption	Consumption of jet fuel attributed to the state in a single year	Million barrels	EIA, 2017
Payload	Total annual payload for all departing domestic flights for each U.S. airport	Pounds	BTS, 2017b

Equation 28

$$\text{Community aviation gasoline consumption} = \text{State aviation gasoline consumption} \times \frac{\sum_{city\ airports} \text{Payload}}{\sum_{state\ airports} \text{Payload}}$$

Table B49. Data sources to estimate community aviation gasoline consumption

Data element	Definition	Units	Source
City aviation gasoline consumption	Consumption of aviation gasoline attributed to the city	Thousand gallons	Calculated

Aviation gasoline consumption	Estimated private and commercial use of aviation gasoline in each state in a single year	Thousand gallons	FHWA, 2016
Payload	Total annual payload for all departing domestic flights for each U.S. airport	Pounds	BTS, 2017b

Methodological and Data Assumptions & Limitations

This approach assumes that:

- The amount of fuel used for departing flights is equal to the fuel used on arriving flights, therefore this methodology also assumes that half of the fuel used for departing flights is equal to half of the fuel used for arriving flights, so the fuel consumed by each airport serves as a proxy for the origin-destination allocation;
- There is a positive correlation between fuel consumption and payload;
- The ratio of jet fuel consumed to aviation gasoline consumed is the same for all airports within a state.

Limitations to this approach include:

- All fuel consumption is attributed to certificated U.S. carriers and foreign carriers that have at least one point of service in the U.S. that report their air traffic information to BTS – there may be un-certificated aviation activity that may not be captured;
- Cannot allocate private and commercial flights out of the airport-specific fuel data;
- Airports are assigned to a community based on the physical address. Did not estimate the allocation of activity from an airport that may serve a nearby community that is adjacent to the community within which the airport is located.

Emission Factors

The methodology uses emission factors from the U.S. EPA's Center for Corporate Climate Leadership Emission Factors Hub (EPA, 2015). These are U.S.-specific emission factors. Table B50. contains the emission factors compiled.

Table B50. U.S. Emission Factors for Aviation Activity

Fuel Type / Vehicle Type	**CO_2 Factor (g / gallon)**	**CH_4 Factor (g / gallon)**	**N_2O Factor (g / gallon)**
Aviation Gasoline / Aviation Gasoline Aircraft	8,310	7.06	0.11
Kerosene-Type Jet Fuel	9,750	0.00	0.30

Source: Environmental Protection Agency. (2015). "Center for Corporate Climate Leadership Emission Factors Hub." Retrieved from https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

References:

Bureau of Transportation Statistics. (2017a). “Air Carrier Statistics Database Data Profile.” Retrieved from https://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=111

This webpage contains a glossary of air carrier statistics terms and definitions.

Bureau of Transportation Statistics. (2017b). “Air Carriers: T-100 Domestic Segment (All Carriers), 2015.” Retrieved from https://www.transtats.bts.gov/Tables.asp?DB_ID=111&DB_Name=Air%20Carrier%20Statistics%20%28Form%2041%20Traffic%29-%20All%20Carriers&DB_Short_Name=Air%20Carriers

This dataset contains domestic and international airline segment data from certificated U.S. air carriers and foreign carriers having at least one point of service in the United States. Data include annual payload for each airport for all originating domestic flights.

Energy Information Administration. (2017). “State Energy Data System (SEDS): 1960-2015.” Retrieved from https://www.eia.gov/state/seds/seds-data-complete.php?sid=US#Consumption

SEDS contains comprehensive state-level estimates of energy production, consumption, prices and expenditures by source and sector, including jet fuel consumption by state.

Environmental Protection Agency. (2015). “Center for Corporate Climate Leadership Emission Factors Hub.” Retrieved from https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

EPA provides a set of default emission factors for greenhouse gas reporting.

Federal Highway Administration. (2016). “Highway Statistics 2015: Non-Highway Use of Gasoline.” Retrieved from https://www.fhwa.dot.gov/policyinformation/statistics/2015/

The Highway Statistics Series brings together data collected from federal, state, and local agencies relating to highway transportation in twelve major areas, including highway travel, motor fuel, and performance indicators. This series contains data on the consumption of aviation gasoline.

Off-Road

Subsector Summary

GHG emissions within the Off-Road subsector result from the consumption of fuel for off-road vehicles that serve transportation premises such as equipment and off-road vehicles at airports and other terminals. Emissions for other off-road vehicles used at for activities such as construction and agriculture are included in the Stationary Energy sector. The GHG emitting activity focused on in this subsector is fuel consumption (gasoline and diesel) for off-road equipment.

Inclusions:

For the United States, based on available data and method, activity data produced includes:

- **Gasoline** and **diesel fuel** consumption from airport ground support equipment operating at airports within the boundary of a designated community.
- **Gasoline** and **diesel fuel** consumption from railroad maintenance operating at lengths of rail that serve a designated community.

Exclusions:

Due to lack of data, this methodology does not include:

- **Fuel** or **electricity** consumption from support equipment at ports and other transport facilities.

Due to CRF guidelines, this methodology does not include the following, which would be reported under the Stationary Energy sector:

- **Fuel** or **electricity** consumption from off-road activities on industrial or commercial premises.
- **Fuel** or **electricity** consumption from off-road activities on agricultural land.

Activity Data Coverage

Table B51 contains the community-scale activity data, and associated emission scope, for the Off-road subsector provided for the United States.

Table B51. Allocated activity data, units, and emission sources

Emissions Source	Definition	Units	Scope
Airport ground equipment gasoline	The amount of gasoline consumed for a single year from all airport ground equipment from all airports located with the community boundary	Trillion Btus	Scope 1
Airport ground equipment diesel fuel	The amount of diesel consumed for a single year from all airport ground equipment from all airports located with the community boundary	Trillion Btus	Scope 1
Railroad maintenance equipment gasoline	The amount of gasoline consumed for a single year from all railroad maintenance equipment from all Class I railroads serving a designated community	Trillion Btus	Scope 1

Railroad maintenance equipment diesel fuel	The amount of gasoline consumed for a single year from all railroad maintenance equipment from all Class I railroads serving a designated community	Trillion Btus	Scope 1

Allocation Methodology

Airport Ground Equipment Fuel Consumption

This methodology disaggregates the national amount of fuel consumed by airport ground equipment, for each fuel type, by the proportion of total payload of all airports within a community compared to the total national payload. Payload serves as a proxy for the amount of both passengers and freight that moves through each airport. The Bureau of Transportation Statistics defines payload as the "certificated takeoff weight of an aircraft, less the empty weight, less all justifiable aircraft equipment, and less the operating load (consisting of minimum fuel load, oil, flight crew, steward's supplies, etc.)" (BTS, 2017a).

Equation 29 and Equation 30 provide community-level airport ground equipment fuel consumption.

Equation 29

$$\text{Community airport ground equipment gasoline consumption} = \text{National airport ground equipment gasoline consumption} \times \frac{\sum_{community\ airports} \text{Payload}}{\sum_{country\ airports} \text{Payload}}$$

Table B52. Data sources to estimate community airport ground equipment gasoline consumption

Data element	Definition	Units	Source
Community airport ground equipment gasoline consumption	Consumption of gasoline for airport ground equipment attributed to the community	Trillion Btus	Calculated
National airport ground equipment gasoline consumption	Consumption of gasoline for airport ground equipment attributed to the community in a single year	Trillion Btus	ORNL, 2017
Payload	Total annual payload for all departing domestic flights for each U.S. airport	Pounds	BTS, 2017b

Equation 30

$$\text{Community airport ground equipment diesel consumption} = \text{National airport ground equipment diesel consumption} \times \frac{\sum_{community\ airports} \text{Payload}}{\sum_{country\ airports} \text{Payload}}$$

Table B53. Data sources to estimate community airport ground equipment diesel consumption

Data element	Definition	Units	Source
Community airport ground equipment diesel consumption	Consumption of diesel for airport ground equipment attributed to the community	Trillion Btus	Calculated
National airport ground equipment diesel consumption	Consumption of diesel for airport ground equipment attributed to the community in a single year	Trillion Btus	ORNL, 2017
Payload	Total annual payload for all departing domestic flights for each U.S. airport	Pounds	BTS, 2017b

Methodological and Data Assumptions & Limitations

This approach assumes that:

- There is a correlation between the use, and therefore fuel consumption, of airport ground equipment and the total payload of airports within a community boundary.

Limitations to this approach include:

- All airport ground support emissions are allocated to the community where the airports are located although the airport may serve many other surrounding communities.

Railroad Maintenance Equipment Fuel Consumption

This methodology disaggregates the national amount of fuel consumption by railroad maintenance equipment, broken down by fuel type, by the proportion of county Class I railroad miles compared to the national total of Class I railroad miles. The county-level disaggregation is then further disaggregated to the community level using the proportion of population.

Equations 31 and 32 demonstrate the approach used to disaggregate national railroad maintenance equipment fuel consumption to the community level.

Equation 31

$$\begin{aligned}&\text{Community railroad maintenance equipment gasoline consumption}\\&\quad= \text{National railroad maintenance equipment gasoline consumption}\\&\quad\times \frac{\text{County railroad miles of Class I railroad}}{\text{National railroad miles of Class I railroads}} \times \frac{\text{Community population}}{\text{County population}}\end{aligned}$$

Table B54, Data sources to estimate community railroad maintenance equipment gasoline consumption

Data element	Definition	Units	Source

Community railroad maintenance equipment gasoline consumption	Consumption of gasoline for railroad maintenance equipment attributed to the community	Trillion Btus	Calculated
National railroad maintenance equipment gasoline consumption	National consumption of gasoline for railroad maintenance equipment	Trillion Btus	ORNL, 2017
Miles of rail	Miles of rail in each county, by railroad owner, in the year 2017	Miles	BTS, 2017c
Population	Estimated population of people in cities and towns in 2015	People	U.S. Census Bureau, 2017

Equation 32

$$\begin{aligned}&\text{Community railroad maintenance equipment diesel consumption}\\&\quad = \text{National railroad maintenance equipment diesel consumption}\\&\quad \times \frac{\text{County railroad miles of Class I railroad}}{\text{National railroad miles of Class I railroads}} \times \frac{\text{Community population}}{\text{County population}}\end{aligned}$$

Table B55. Data sources to estimate community railroad maintenance equipment gasoline consumption

Data element	Definition	Units	Source
Community railroad maintenance equipment diesel consumption	Consumption of diesel for railroad maintenance equipment attributed to the community	Trillion Btus	Calculated
National railroad maintenance equipment diesel consumption	Consumption of diesel for railroad maintenance equipment attributed to the community	Trillion Btus	ORNL, 2017
Miles of rail	Miles of rail in each county, by railroad owner, in the year 2017	Miles	BTS, 2017c
Population	Estimated population of people in cities and towns in 2015	People	U.S. Census Bureau, 2017

Methodological and Data Assumptions & Limitations

This approach assumes that:

- Reported fuel use for railroad maintenance equipment is solely associated with Class I railroads.
- Railroad maintenance equipment is used evenly along each portion of rail.
- Each community in the county is responsible for a share of rail emissions, based on its proportion of population in the county.
- Railroad lines did not substantially change between 2015 and 2017.

Emission Factors

The methodology uses emission factors from the U.S. EPA's Center for Corporate Climate Leadership Emission Factors Hub (EPA, 2015), as presented in Table B56.

Table B56. U.S. Emission Factors for Aviation Activity

Fuel Type / Vehicle Type	CO_2 Factor (g / gallon)	CH_4 Factor (g / gallon)	N_2O Factor (g / gallon)
Motor Gasoline / Other Gasoline Non-Road Vehicles	8,780	0.50	0.22
Diesel Fuel / Other Diesel Non-Road Vehicles	10,210	0.57	0.26

References

Bureau of Transportation Statistics. (2017a). "Air Carrier Statistics Database Data Profile." Retrieved from https://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=111

This webpage contains a glossary of air carrier statistics terms and definitions.

Bureau of Transportation Statistics. (2017b). "Air Carriers: T-100 Domestic Segment (All Carriers), 2015." Retrieved from https://www.transtats.bts.gov/Tables.asp?DB_ID=111&DB_Name=Air%20Carrier%20Statistics%20%28Form%2041%20Traffic%29-%20All%20Carriers&DB_Short_Name=Air%20Carriers

This dataset contains domestic and international airline segment data from certificated U.S. air carriers and foreign carriers having at least one point of service in the United States. Data include annual payload for each airport for all originating domestic flights.

Bureau of Transportation Statistics. (2017). "Railroad Lines." Retrieved from http://osav-usdot.opendata.arcgis.com/datasets?keyword=Rail

Provides the mileage of rail in each county, by the railroad owner for each segment.

Environmental Protection Agency. (2015). "Center for Corporate Climate Leadership Emission Factors Hub." Retrieved from https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

EPA provides a set of default emission factors for greenhouse has reporting.

Oak Ridge National Laboratory. (2017). "Transportation Energy Data Book: Edition 36 – Off-Highway Transportation-Related Fuel Consumption from the Nonroad Model, 2015." Retrieved from http://cta.ornl.gov/data/index.shtml

Provides data on off-road activity fuel consumption, including airport ground equipment and railroad maintenance equipment.

U.S. Census Bureau. (2017). "City and Town Population Totals: 2010-2016." Retrieved from https://www.census.gov/data/datasets/2016/demo/popest/total-cities-and-towns.html

The U.S. Census Bureau projects population for cities and towns based on 2010 census.

Waste Sector

This section details the calculation approaches and data sources for producing community-level activity data and emission factors for the waste sector. For the United States, the data estimation methodologies cover the following subsectors, initially for the year 2015:

Table B57. Waste Sector Coverage

Waste Sector	
Solid waste	Included
Biological waste	Included
Incinerated and burned waste	Not currently estimated
Wastewater	Included

Solid Waste

Subsector Overview

This section covers the activity data and emission factors needed for communities in the United States to estimate emissions from the treatment of municipal solid waste (MSW) disposed of at landfill facilities or open dumps (solid waste disposal). Emissions estimates from solid waste disposal are influenced by the following three factors:

1) The mass of community-generated waste treated in landfills or open dumps;
2) The methane generation potential; and
3) The amount of methane recovered.

Significant methane (CH_4) emissions occur during solid waste disposal and treatment processes. The following section discusses methods for estimating the mass of waste, methane generation potential, degradable organic carbon emission factors, and methane recovered at the community level—all which impact total methane emitted.

Inclusions

For the United States, based on available data and methods, the data provided includes:

- Community-specific **mass of waste landfilled at registered facilities** based on national data allocated proportionally with population.
- Community-specific **methane correction factors**.
- **Methane Generation Potential (L_0)** based on degradable organic carbon, landfill management type and fraction of methane in landfill gas nationally.
- **Oxidation Factors (OX)** based on landfill management practice.
- Community-specific mass of **methane recovered** based on national data allocated proportionally with population.

Exclusions

Due to the unavailability of data, the data provided excludes:

- The combustion, or flaring, of landfill gas for non-energy purposes[18]
- The combustion of solid waste for non-energy purposes[19]

While other gases are also emitted through the collecting, sorting, and transporting of solid waste to treatment facilities—namely biogenic carbon dioxide, non-methane volatile organic compounds, and nitrous oxide—this methodology focuses on the activity data and emission factors required to estimate methane emission only. If desired, communities may consult international resources such as the IPCC guidelines for national reporting or local guidance documents, if available, to estimate non-methane GHG emissions from solid waste disposal

Activity Data Coverage

Table B58 details the relevant activity data for the solid waste subsector.

Table B58: Activity data, units, and scope for solid waste disposal subsector

Activity Data	Definition	Units	Emissions Scope
Mass of Waste	The mass of waste disposed at unmanaged, managed, sanitary landfills and open dumps within a community boundary, regardless of where the waste was generated.	Tonnes	Scope 1
	The mass of waste generated within a community boundary but diverted to an external landfill or open dump for disposal	Tonnes	Scope 3
Methane Generated	The amount of CH_4 generated per ton of solid waste based treated within a community boundary	M^3/ton	Scope 1
	The amount of CH_4 generated per ton of solid waste based treated outside a community boundary	M^3/ton	Scope 3
Methane Recovered (If data are available)	The mass of methane recovered at landfills or open dumps from waste treated within a community boundary	Tonnes	Scope 1
	The mass of methane recovered at landfills or open dumps from waste generated by a community but treated outside a community boundary	Tonnes	Scope 3

For the solid waste subsector, this methodology allows for the estimation of two primary types of activity data: 1) mass of waste and 2) methane recovered. Standard accounting principles recommend that these data be reported in two separate emissions scopes (Wee Kean 2014). For mass of waste these are: scope 1: solid waste disposed at unmanaged, managed, or sanitary landfills or open dumps within a community boundary, regardless of whether the waste originated within community boundaries; and scope 3: solid waste disposed at unmanaged, managed, or sanitary landfills or open dumps outside of a community boundary but originating from within the community boundary. Similarly, for methane recovered, scopes are categorized by recovery occurring within a community's boundary (scope 1) and recovery outside of a community's boundary but stemming from activity occurring within the community (scope 3).

The methods described below allow for estimating mass of solid waste disposed and methane recovered at the community-scale. However, they do not allow for the subdivision of activity data by scopes 1 and 3. This limitation stems from a lack of supplementary information with which to determine the community-specific origin of waste streams and is discussed further in the Allocation Methodology and Data Limitations and Improvement sections below.

Allocation Methodology

In the U.S, waste disposal facilities are not mandated by law to record and report their incoming waste hauls and methane recovery numbers. Although some facilities do provide this information voluntarily, the lack of comprehensive coverage makes providing estimations, using the more robust facility-based approach, difficult. Hence, this methodology instead uses a population-based approach to allocate national-level solid waste disposal and methane recovery activity data to the community level to account limitations of the source data used. A lack of geographically resolved data on waste generation and flows in and out of community boundaries necessitates the use of national totals and a scaling factor based on population data, which is generally viewed as a viable proxy for waste generation activities in the absence of more specific data such as waste landfilled by facility or waste imported or exported by community (Wee Kean 2014).

The use of a population-based approach means that estimates produced by this methodology follow a community-induced accounting framework for each community rather than a scopes framework. In other words, it estimates the amount of waste generated by the community and resulting emissions. Scope 1 and 3 emissions are implicitly covered, at least partially, the method does not allow for allocating data explicitly by scope.

Activity Data – Mass of Waste (Landfills)

In the absence of a centralized data platform, which would allow U.S states to keep track of their mass and composition estimates, this methodology includes Equation 33 below to calculate the community-specific mass of waste landfilled based on publicly available national estimates reported in the U.S Census. :

Equation 33

$$\text{Landfilled MSW}_{community} = \text{Landfilled MSW}_{national} \times \frac{\text{Community Population}}{\text{National Population}}$$

Table B59. Data elements and sources

Data Element	Definition	Units	Data Source
Landfilled $MSW_{community}$	Mass of community -generated organic waste landfilled	Tonnes	Calculated
Landfilled $MSW_{nationally}$	Mass of nationally generated organic waste landfilled	Tonnes	EPA (2014; 2015; & 2016)
Community Population	Total number of residents living within community boundary	Persons	U.S Census (2016)
National Population	Total number of persons living in the United States	Persons	U.S Census (2016)

For Equation 33, the mass of landfilled waste reported nationally (EPA 2014; 2015; & 2016) is allocated to each community using the community population at the census place level reported under the U.S. Census, 2016. The proportion of community to national population is used as a weighting factor to disaggregate the national waste generated locally. The final outcome results in a community-specific mass of waste that can represent an average community's generation habits.

Activity Data – Mass of waste (Open dumping)

Solid waste in the U.S. is most commonly disposed of through modern, managed landfills (EPA, 2017). The disposal of waste at illegal dumping sites is considered to have not occurred after 1980 and thus any emissions associated with illegal dumping are considered inconsequential to report in the current inventory year (EPA, 2017). This methodology relies on EPA data and thus applies the same convention by assuming that all waste is disposed of in managed landfills in compliance with relevant regulations. Thus, open dumping activity data are not included as a source in this inventory.

Activity Data – Methane Correction Factor (MCF)

CH_4 generation rates are dependent on landfill management practices. As discussed above, EPA (2017) assumes that all waste has been deposited in managed anaerobic landfills post-1980, and this methodology applies the same convention. The IPCC (2006) MCF value of 1.0 (unitless) for managed anaerobic landfills is thus used for the purposes of this methodology.

Activity Data –Methane Recovered

For inventories using a facility-based approach, accounting for landfill methane recovery is necessary for providing an accurate estimate of CH4 produced during the management of solid waste. The volume of methane recovered during treatment process is first subtracted from the overall methane produced before the final number is reported. Although a methane recovery database exists in the US, the method for recording such data is regionally inconsistent making the use of the database for this methodology somewhat unreliable. However, for cases where these data are comprehensive and a consistent methane data collection framework is established, the calculation represented in Equation 34 is used estimate the community-specific mass of methane recovered:

Equation 34

$$\text{Methane Recovery}_{community} = \text{Methane Recovery}_{nationally} \times \frac{\text{Community Population}}{\text{National Population}}$$

Table B60. Data elements and sources

Data Element	Definition	Units	Data Source
$\text{Methane Recovery}_{\text{community}}$	Mass of community - generated methane recovered from landfill facilities	Tonnes	Calculated
$\text{Methane Recovery}_{\text{nationally}}$	Mass of nationally generated methane recovered from landfill facilities	Tonnes	EPA LMOP (2018)
Community Population	Total number of residents living within community boundary	Persons	U.S Census (2016)
National Population	Total number of persons living in the United States	Persons	U.S Census (2016)

For Equation 34, U.S. population estimates at the census place and national level (U.S. Census, 2016) are used to divide the number of persons living within a community boundary by the total U.S. population reported in a calendar year. This result is then multiplied by the mass of methane recovered nationally (EPA, 2018) to estimate a community-specific mass of methane recovered.

Emission Factors

This methodology allows for the estimation of methane from solid waste disposal using the default, Tier 1 Methane Commitment method in accordance with IPCC guidance (IPCC, 2000; IPCC, 1996). This method relies on the assumption that all potential CH_4 emissions occur within the same year the waste is disposed (IPCC, 2000). While this does not reflect the true, temporal nature of waste sector emissions that can be captured through the Tier 2 First Order Decay (FOD) method, the commitment method is seen as a viable approach in the absence of time-series data on waste disposal patterns, particularly if the amount and composition of deposited waste has been relatively stable over time (IPCC, 200).

Under this method, the solid waste disposal emission factor (EF) is a combination of two factors, the methane generation potential (L_0) and the oxidation factor (OX). In the absence of data on facility-specific emission factors, this methodology relies on the default factor for OX derived from IPCC (2006).

Equation 35

$$EF = L_o * (1 - OX)$$

Table B61. Data elements and sources

Data Element	Definition	Units	Data Source
L_O	Methane Generation Potential – the amount of methane generated per tonne of waste	Tonnes CH_4/tonne waste	Equation 36
OX	Oxidation factor (Methane Oxidized in top layer)	Unitless	IPCC (2006)

Oxidation Factor (OX)

The landfill oxidation factor represents the percentage of carbon that is oxidized during decomposition. For this variable, the IPCC (2006) default value of 0.1 (for well-managed landfills) is used in this methodology.

Methane Generation Potential (L_0)

Methane generation potential (L0) is itself a combination of several additional factors: The Methane Correction Factor (MCF); Degradable Organic Carbon (DOC), weighted by waste stream type (discussed below); the fraction of waste degraded anaerobically (DOCf); the fraction of landfill gas that is methane (F); and the methane to carbon ratio. As with above, each of these values is derived from IPCC default values due to a lack of facility-specific data.

The calculation for methane generation potential of community -specific landfilled waste is provided in Equation 36:

Equation 36

$$L_0 = MCF * DOC * \ DOC_F \ * F * \ {}^{16}/_{12}$$

Table B62. Data elements and sources

Data Element	Definition	Units	Data Source
MCF	Methane Correction Factor (based on management type) – part of the landfilled materials that is left to degrade anaerobically.	Unitless	IPCC (2006)
DOC	Degradable organic carbon – the portion of the waste stream that can decompose under aerobic conditions	Tonnes C/tonne waste	IPCC (2006); EPA (2016)

DOC_F	The fraction of DOC ultimately degraded anaerobically	Unitless	IPCC (2006)
F	The fraction of methane in landfill gas	Unitless	IPCC (2006)
$^{16}/_{12}$	Methane to carbon ratio	Unitless	IPCC (2006)

DOC for the total waste stream is calculated as a weighted average of the degradable content of various types of waste (e.g. food, textiles, paper/cardboard) within the total waste stream. IPCC guidance provides separate DOC values for eleven broad waste types (IPCC, 2006). These eleven waste types and their corresponding DOC values are contained in table B63.

Table B63. 2006 IPCC default values for major waste streams

Waste Stream	DOC (tonnes C/ tonne waste)
A. Food	0.15
B. Garden and park waste	0.20
C. Paper/cardboard	0.40
D. Wood	0.43
E. Textiles	0.24
F. Nappies	0.24
G. Rubber and leather	-
H. Plastics	-
I. Metal	-
J. Other, inert waste	-

Source: IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 3: Solid Waste Disposal, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

The IPCC also provides the regional MSW composition data for North America which were assumed to reflect the waste characteristics in the U.S. Thus, these U.S.-specific relative shares of each waste type within the total landfilled waste stream (EPA, 2014; EPA, 2015; EPA, 2016) are combined with their corresponding default DOC values (IPCC, 2006) to generate the weighted average required for Equation 36 above. Equation 37 provides the calculation of the weighted average DOC for the total landfilled waste stream.

Equation 37

$$DOC_{total\ waste\ stream} = \sum_i (DOC_i \times Fraction_i)$$

Table B64. Data elements and sources

Data Element	Definition	Units	Data Source
$DOC_{total\ waste\ stream}$	Fraction of degradable organic carbon in total landfilled waste stream (weighted average)	Unitless	Calculated
DOC_i	Default value for fraction of degradable organic carbon in waste type	Unitless	Table B63 / (IPCC, 2006)
$Fraction_i$	Fraction of waste type in total landfilled waste stream	Unitless	(EPA, 2016)

Source: IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 3: Solid Waste Disposal, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

DOC producing waste categories reported by EPA generally align with IPCC categories A–E in Table B63, with few exceptions. Although waste stream F is a producer of DOC, no data are reported on a national level by EPA hence the emissions from this stream cannot be estimated. Additionally, emissions are produced from industrial wastes, which have their unique set of DOC values. However, in the absence of data for this category, this methodology omits community-specific activity data or emission factors for industrial waste.

Emission Factor Summary

Table B65, below, presents a summary of the values used in the calculation of the emission factor for each of the five waste streams estimated.

Table B65. 2006 IPCC default emission factors used in this methodology

	Waste Types				
MSW Variables	**Food**	**Garden**	**Paper**	**Wood**	**Textiles**
MCF (landfill site – managed)	1.0	1.0	1.0	1.0	1.0
DOC (tonnes C/tonne waste)	0.15	0.20	0.40	0.43	0.24
DOC_f (fraction of DOC ultimately degraded anaerobically)	0.5	0.5	0.5	0.5	0.5
OX (top layer methane oxidation)	0.1	0.1	0.1	0.1	0.1
F (fraction of methane in landfill gas)	0.5	0.5	0.5	0.5	0.5

Source: IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 3: Solid Waste Disposal, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

General Assumptions & Limitations

Mass of Waste

- Due to reliance on the Methane Commitment method (IPCC, 2000; IPCC, 1996), it is assumed that all emissions from waste occurs within the same calendar year in which it was disposed of.
- The inventorying process only accounts for solid waste disposal which occurs at managed landfill facilities since open dumping is considered to have negligible effects on emissions due to it being outlawed by 1980.
- Mass of waste generated, measured as the amount of waste disposed of in managed landfills in the U.S., is proportionally related to population

Emission Factors

- The EPA (2014; 2015; 2016) *Advancing Sustainable Materials Management fact sheets* provides detailed waste generation, recovery, and landfill discarded wastes for each waste stream at the national level. In the absence of national or community-specific datasets on industrial waste, this methodology is unable to determine a community-specific DOC estimate for this waste stream. [20]
- In the absence of community-specific data on waste composition, it is assumed the national average for the composition of every community's waste stream.

Methane Correction Factor

- The EPA (2017) assumes that all waste post-1980 were deposited into managed, modern landfills which assume an MCF value of 1.0. Therefore, it is assumed an MCF of 1.0 for all community landfill facilities.

Methane Recovery

- The EPA (2018) LMOP database does not provide information for methane recovered after 2014, therefore it is assumed that methane recovery estimates for 2015 and later have held constant since 2014.
- It is assumed the methane recovery at managed landfills from a given community's waste stream equals that of the national average rate of methane recovery
- Amount of methane recovered from a given waste stream is related proportionally to the amount of waste generated within the boundary from which the waste originates.

Potential Improvement

- As detailed above, this methodology assumes that the amount of waste generated and recovered are both related proportionally to population. By scaling national level totals with population data, the method further assumes that national averages are consistent across all regions, states, and communities. To address these limitations, future iterations of this method will look to additional supplementary data on economic and social stratification to account for the differences in the likely per-capita rates of waste disposal and methane recovery. As an example, EPA's LMOP (EPA, 2018) database may allow for the accounting of state-by-state differences in the average rate of methane recovery, based on facility-level data on methane capture.

References:

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 3: Solid Waste Disposal, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

Provides default values for the fraction of degradable organic content present in waste stream.

IPCC. (2000). Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Waste. Available at https://www.ipcc-nggip.iges.or.jp/public/gp/english/5_Waste.pdf

Includes an updated method for estimating methane emissions from MSW using the methane commitment estimate model.

IPCC (1996). IPCC Guidelines for National Greenhouse Gas Inventories. Volume. 1: Greenhouse gas inventory reporting instructions. Volume. 2: Greenhouse gas inventory workbook. Volume 3: Greenhouse gas inventory reference manual. Available at http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html

Provides a method for estimating methane emissions from MSW using the methane commitment estimate model.

United States Census Bureau (2016). *City and Town Population Totals.* Retrieved December 21st, 2017 from https://www.census.gov/data/tables/2016/demo/popest/total-cities-and-towns.html

This website provides annual statistics on population demography in U.S states, cities and towns.

United States Environmental Protection Agency (U.S. EPA) 2018. Landfill Methane Outreach Program. U.S. Environmental Protection Agency, Washington, D.C. Available at https://www.epa.gov/lmop/landfill-technical-data

Landfill database with estimates on landfill gas collected from municipal solid waste facilities from 1929 through 2008.

United States Environmental Protection Agency (U.S. EPA) 2017. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2015 EPA 430-P-17-001 US Environmental Protection Agency, Washington, DC. Available online at https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report

Provides methane correction factors based on landfill management type for existing landfills in the U.S.

United States Environmental Protection Agency (U.S. EPA). 2016 Advancing Sustainable Materials Management: Facts and Figures 2014. Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available online at https://www.epa.gov/sites/production/files/2016-11/documents/2014_smm_tablesfigures_508.pdf

Provides waste generation, recycling, composting, combustion with energy recovery and landfilling of materials in MSW in 2014.

United States Environmental Protection Agency (U.S. EPA). 2015 Advancing Sustainable Materials Management: Facts and Figures 2013. Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available online at https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_fs.pdf

Provides waste generation, recycling, composting, combustion with energy recovery and landfilling of materials in MSW in 2013.

United States Environmental Protection Agency (U.S. EPA). 2014 Advancing Sustainable Materials Management: Facts and Figures 2012. Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available online at https://www.epa.gov/sites/production/files/2015-09/documents/2012_msw_fs.pdf

Provides waste generation, recycling, composting, combustion with energy recovery and landfilling of materials in MSW in 2012.

Biological Waste

Subsector Overview

This section covers the activity data and emission factors needed for communities in the United States to estimate emissions from the biological treatment of solid waste (biological waste). Biological waste estimates are influenced by two factors:

1) The mass of community-generated waste treated in a calendar year, via compost production and anaerobic digestion, and
2) The moisture content of the waste being treated.

Methane (CH_4) and nitrous oxide (N_2O) are the main gases emitted during these treatment processes. The methods for estimating the mass of waste, methane recovery, and GHG-specific emission factors in the United States are outlined below.

Inclusions

For the United States, based on available data and methods, the data produced includes:

- Community-specific **mass of waste biologically treated** at permitted facilities based on national data allocated proportionally with population.
- Community-specific **emission factors** based on location-specific assumptions of the biological treatment technique and the moisture content of waste sent to facilities.

Exclusions

Due to the unavailability of data, the data provided excludes:

- **Facility-specific mass of waste composted**

- **Community-specific mass of waste anaerobically digested.**
- **Mass of waste composted outside of designated waste facilities** (e.g., private home composting)
- **Methane Gas Recovery** at compost facilities with recovery systems in place.

Activity Data Coverage

Communities should report emissions from the mass of waste treated based on emissions scope. For biological waste, this includes all emissions produced from composting and anaerobic digestion treatment facilities within a community boundary, regardless of where the waste was generated (scope 1), as well as all emissions produced from composting and anaerobic digestion treatment at facilities outside the community boundary (scope 3).

Table B66. Activity data, units, and scope covered under biological waste

Activity Data	Definition	Units	Gases Reported	Emissions Scope
Biological Waste	The mass of organic waste disposed of and treated within the community boundary, through composting or anaerobic digestion techniques, regardless of where the waste was generated	Tonnes	CH_4, N_2O	Scope 1
	The mass of organic waste generated within the community boundary which is treated through composting or anaerobic digestion techniques at facilities outside the community boundary.	Tonnes	CH_4, N_2O	Scope 3
Methane Recovered (If data are available)	The mass of CH_4 recovered at biological treatment facilities from waste treated within the community boundary.	Tonnes	CH_4	Scope 1
	The mass of CH_4 recovered at biological treatment facilities from waste generated by a community but treated outside the community boundary.	Tonnes	CH_4	Scope 3

Allocation Methodology

In the U.S, biological treatment facilities are not mandated by law to record and report their incoming waste hauls and methane recovery numbers. Although some facilities do provide this information voluntarily, the lack of comprehensive coverage makes providing estimations, using the more robust facility-based approach, difficult. Hence, this methodology instead uses a population-based approach to allocate national-level biological waste disposal data—specifically composting—to the community level to account limitations of the source data used. A lack of geographically resolved data on biological waste generation and flows in and out of community boundaries necessitates the use of national totals and a scaling factor based on population data, which is generally viewed as a viable proxy for waste generation activities in the absence of more specific data such as waste biologically treated by facility (Wee Kean 2014).

The use of a population-based approach means that estimates produced by this methodology follow a community-induced accounting framework for each community rather than a scopes framework. In other words, it estimates the amount of biological waste generated by the community and resulting emissions. Scope 1 and 3 emissions are implicitly covered, at least partially, the method does not allow for allocating data explicitly by scope

Activity Data – Mass of Waste Composted

In the absence of a centralized data platform, which would allow U.S states to keep track of their estimates on mass of waste biologically treated, this methodology uses Equation 38 below to calculate the community-specific mass of waste composted based on publicly available national estimates reported in the U.S Census.:

Equation 38

$$\text{Composted MSW}_{community} = \text{Composted MSW}_{national} * \frac{\text{Community Population}}{\text{National Population}}$$

Table B67. Data elements and sources

Data Element	Definition	Units	Data Source
$\text{Composted MSW}_{community}$	Mass of community-generated organic waste composted	Tonnes	Calculated
$\text{Composted MSW}_{national}$	Mass of nationally generated organic waste composted	Tonnes	EPA (2017)
Community Population	Total number of residents living within a U.S. community boundary	People	U.S Census (2016)
National Population	Total number of persons living in the United States	People	U.S Census (2016)

As outlined in Equation 38, 2016 U.S Census data sets are used to divide the number of persons living within the community boundary by the total U.S. population reported in a calendar year. This result is then multiplied by the mass of composted waste reported nationally by EPA (2017) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2015 to estimate the community-specific mass of organic composted.

Activity Data – Mass of Waste Anaerobically Digested

Currently, there are no national or state level datasets available on the mass of waste being treated through anaerobic digestion (AD). As a result, this methodology is neither able to provide an activity data estimate for waste treated through AD nor able to account for what fraction of biological waste emissions are represented by AD represents.

Activity Data – Methane Recovery

For inventories using a facility-based approach, accounting for methane recovery from biological treatment is necessary for providing an accurate estimate of CH4 produced during the management process. The volume of methane recovered during treatment is first subtracted from the overall methane produced before the final number is reported. Although a methane recovery database exists in the US, the method for recording such data is regionally inconsistent making the use of the database for this methodology somewhat unreliable. Hence, the CH4 recovery at a community level cannot be estimated easily. However, for cases where these data are comprehensive and a consistent methane data collection framework is established, the following methodology which calculates the amount of methane recovered at a community-level can be used.

Equation 39

$$\text{Methane Recovery}_{community} = \text{Methane Recovery}_{nationally} \times \frac{\text{Community biologically treated waste mass}}{\text{National biologically treated waste mass}}$$

Table B68. Data elements and sources

Data Element	Definition	Units	Data Source
$\text{Methane Recovery}_{\text{community}}$	Mass of community -generated methane recovered from biological treatment facilities	Tonnes	Calculated
$\text{Methane Recovery}_{\text{nationally}}$	Mass of nationally generated methane recovered from biological treatment facilities	Tonnes	EPA LMOP (2018)
Community Waste biologically treated	Total mass of waste biologically treated within community boundary	Tonnes	EPA (2017)
National Waste biologically treated	Total mass of waste biologically treated within the United States	Tonnes	EPA (2017)

Emission Factors

CH_4 and N_2O emissions from the biological treatment of waste are calculated using emission factors provided in the 2006 IPCC guidelines. These factors are recorded in grams per kilogram of waste treated and identified below in Table B69. EPA MSW data are reported in wet weight, so used is the wet weight emission factors of 4 g CH_4/kg compost (methane) and 0.3 g N_2O/kg compost (nitrous oxide) (EPA 2017).

Table B69. 2006 IPCC Emission Factors per treatment type in g GHG/kg waste

Treatment Type	**CH_4** (g per kg of waste treated)	**N_2O** (g per kg of waste treated)
Compost (dry weight)	10	0.6
Compost (wet weight)	4	0.24
Anaerobic Digestion (dry weight)	2	None
Anaerobic Digestion (wet weight)	0.8	None

Source: IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 4: Biological Treatment of Solid Waste, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_4_Ch4_Bio_Treat.pdf

General Assumptions & Limitations

Mass of Waste

- Because there is no comprehensive data set of composting facilities and the communities they serve, the population-based approach does not allow assigning emissions to scope 1. All emissions are therefore reported under scope 3. Communities with composting facilities located within their boundary can choose to fold these scope 3 emissions into their scope 1 reported estimates or allocate accordingly with neighboring communities.
- The *U.S. GHG Inventory* (EPA, 2017) only provides composting details under its biological treatment subsection. Therefore, it is assumed that this is the sole method for biologically treating waste in the United States and that no waste is treated biologically through anaerobic digestion at biogas facilities. As such, this is the only treatment option that this approach estimates.
- The use of the national estimates of composted waste assumes that composting is an equally available practice across all communities. This assumption is necessary without additional data on the location of all domestic composting facilities. However, for those communities where composting is not a known practice, these estimates should be excluded from their reporting figures.

Emission Factors

- The *U.S. GHG Inventory* (EPA, 2017) provides emission factor data for composting on a wet weight basis. It is therefore assumed that this moisture content is standard among waste treated at composting facilities throughout the United States. Thus, for methane, it is assumed a wet weight waste EF of 4.0 g CH_4/kg compost, and for nitrous oxide, it is assumed a wet weight waste EF of 0.3 g N_2O/kg compost.

References:

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, Chapter 4: Biological Treatment of Solid Waste, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_4_Ch4_Bio_Treat.pdf

Report provides the range of default emission factors for methane and nitrous oxides based on moisture content and biological treatment type.

U.S. Census Bureau (2016). *City and Town Population Totals.* Retrieved December 21st, 2017 from https://www.census.gov/data/tables/2016/demo/popest/total-cities-and-towns.html

Website provides annual statistics on population demography in U.S states, cities, and towns.

U.S. Environmental Protection Agency (2017) Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2015 EPA 430-P-17-001 US Environmental Protection Agency, Washington, DC. Available online at https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report

Report provides the estimates for mass of waste composted in the United States from 1990 through 2015 and the U.S selected emission factors for CH_4 and N_2O based on the moisture content of the waste treated at biological facilities.

Incinerated and Burned Waste

Subsector Overview

This section covers the activity data and emission factors needed for communities in the United States to estimate emissions from incineration and open burning (incinerated and burned waste). Incineration and open-burning waste estimates are influenced by three factors:

3) The mass of community-generated waste treated via incineration and open burning,
4) The type of waste and its carbon content, and
5) The type of waste treatment premises.

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the main gases emitted during these treatment processes.

Available Data

There are three types of waste incineration considered: 1) incineration for energy generation; 2) incineration for volume reduction and; 3) open burning.

Energy that is generated via waste incineration is fed into the electric grid and is therefore included elsewhere in the estimates provided for the stationary energy sector. Thus, not provided are estimates for incineration for energy generation.

According to the EPA (2017), incineration for volume reduction produces negligible amounts of emissions in the U.S. that are considered insignificant for inventory reporting. Therefore, this methodology does not provide an estimate for waste incineration for volume reduction.

Given that most waste incineration takes place at waste to energy facilities (EPA, 2017), this methodology assumes that any open burning taking place in the U.S. occurs at a negligible scale and therefore not provided is an estimate for this practice.

References:

U.S. Environmental Protection Agency (2017) Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2015 EPA 430-P-17-001 US Environmental Protection Agency, Washington, DC. Available online at https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report

The U.S. national GHG inventory, which outlines that raw data on incineration and open burning are not included in the waste subsector. Incineration in the U.S takes place at waste to energy facilities and these estimates are reported in the energy sector. Estimates on waste incineration for volume reduction are not included.

Wastewater

Subsector Overview

This section covers the activity data and emission factors needed for communities in the United States to estimate emissions from the treatment and discharge of domestic and industrial wastewater effluent. Wastewater treatment and discharge emission estimates are influenced by five inputs:

1) The organic content in the wastewater - domestic biological oxygen demand (BOD) and industrial chemical oxygen demand (COD),
2) the degree of utilization/discharge pathway,
3) the annual per capita protein consumption,
4) the amount of methane recovered, and
5) the amount of nitrogen sludge removed.

Methane (CH_4) and nitrous oxide (N_2O) are the main gases emitted during the treatment process. The methods for estimating the organic content, degree of utilization, protein consumption, methane recovery, and nitrogen sludge removal in the United States are outlined below.

Inclusions

For the United States, based on available data and methods, the data produced includes:

- **Community-specific domestic BOD values** present in effluent treated.
- **Community-specific emission factors** based on location-specific assumptions on discharge pathways.
- **Average annual per capita protein consumption** based on national assumptions on consumption.
- **Amount of nitrogen removed as sludge.**

Exclusions

Due to the unavailability of data, data provided excludes:

- **The facility-specific volume of industrial wastewater effluent treated** and associated COD values.
- **Volume of effluent treated outside of designated wastewater treatment facilities** (e.g., stagnant water bodies and latrines)
- **Methane gas recovery** at wastewater facilities with recovery systems in place.

Activity Data Coverage

Communities should report emissions from wastewater based on emissions scope. For wastewater treatment and discharge, this includes the mass of methane recovered and municipal wastewater treated within a community boundary regardless of where the wastewater was generated (scope 1), as well as the mass of methane recovered and municipal wastewater generated by a community and treated at facilities outside the community boundary (scope 3).

Table B70. Activity data, units, and scope covered under wastewater treatment and discharge

Activity Data	Definition	Units	Gases Reported	Emissions Scope
Municipal Wastewater	The mass of organics in the municipal wastewater treated within a community boundary regardless of where the wastewater was generated.	Tonnes	CH_4, N_2O	Scope 1
	The mass of organics in the municipal wastewater generated by a community and treated at facilities outside the community boundary	Tonnes	CH_4, N_2O	Scope 3
Methane Recovered (if data are available)	The mass of methane recovered at facilities from wastewater treated within the community boundary.	Tonnes	CH_4	Scope 1
	The mass of methane recovered at facilities from wastewater generated by a community but treated outside the community boundary.	Tonnes	CH_4	Scope 3

Allocation Methodology

In the U.S, wastewater treatment facilities are not mandated by law to record and report their incoming flows and methane recovery numbers. Although some facilities do provide this information voluntarily, the lack of comprehensive coverage makes providing estimations, using the more robust facility-based approach, difficult. Hence, this methodology instead uses a population-based approach to allocate national-level municipal wastewater total organics to the community level to account limitations of the source data used. A lack of geographically resolved data on municipal wastewater flows necessitates the use of national totals and a scaling factor based on population data, which is generally viewed as a viable proxy for waste generation activities in the absence of more specific data such as wastewater treated by facility (Wee Kean 2014).

Based on available data, this methodology uses a population-based approach instead of a facility-based approach to allocate state-level wastewater treatment and discharge activity data to the community level.

Activity Data – Organic Content in Wastewater (Biochemical Oxygen Demand)

This methodology calculates the community-specific organic content in domestic wastewater using the biochemical oxygen demand (BOD) present in the domestic wastewater effluent treated in the U.S. using Equation 40 below:

Equation 40

$$\text{BOD}_{community} = \text{BOD}_{national} * \frac{\text{Community Population}}{\text{National Population}}$$

Table B71. Data elements and sources

Data Element	Definition	Units	Data Source
$\text{BOD}_{\text{community}}$	Community-generated BOD in treated wastewater effluent	Kg BOD/person/day	Calculated
$\text{BOD}_{\text{national}}$	Nationally generated BOD in treated wastewater effluent	kg BOD/capita/day * US Population * 365d days/year	EPA (2017)
Community Population	Total number of residents living within community boundary	People	U.S Census (2016)
National Population	Total number of persons living in the United States	People	U.S Census (2016)

From Equation 40, datasets provided by the 2016 U.S. Census are used to divide the number of persons living within the U.S. community boundary by the total U.S. population reported in a calendar year. This result is then multiplied by the total nationally-generated BOD5 values for wastewater, reported by EPA (2017) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2015, to estimate a community-specific BOD value.[21]

Activity Data – Methane Recovered

For inventories using a facility-based approach, accounting for methane recovery from wastewater treatment is necessary for providing an accurate estimate of CH_4 produced during the management process. The volume of methane recovered during treatment is first subtracted from the overall methane produced before the final number is reported. Currently, no wastewater treatment methane recovery data base exists in the US. Hence, CH_4 recovery at a community level cannot be estimated. However, for cases where these data are comprehensive, and a consistent methane data collection framework is established, the following methodology which calculates the amount of methane recovered at a community-level can be used.

Equation 41

$$\text{Methane Recovery}_{community} = \text{Methane Recovery}_{nationally} \times \frac{\text{Community total organics in wastewater}}{\text{National total organics in wastewater}}$$

Activity Data – Nitrogen in Sludge Removal

Community-specific nitrogen removed as sludge from domestic wastewater effluent is calculated using Equation 42 below:

Equation 42

$$\text{Nitrogen sludge}_{community} = \text{Nitrogen sludge}_{national} * \frac{\text{Community Population}}{\text{National Population}}$$

Table B72. Data elements and sources

Data Element	Definition	Units	Data Source
$\text{Nitrogen sludge}_{\text{community}}$	Community-generated nitrogen removed from wastewater as sludge	kg-N	Calculated
$\text{Nitrogen sludge}_{\text{national}}$	Nationally generated nitrogen removed from wastewater as sludge	kg-N	EPA (2017)
Community Population	Total number of residents living within a community boundary	People	U.S Census (2016)
National Population	Total number of persons living in the United States	People	U.S Census (2016)

As seen in Equation 42, datasets provided by the 2016 U.S. Census are used to divide the number of persons living within a U.S. community boundary by the total U.S. population reported in a calendar year. This result is then multiplied by the national total of nitrogen removed from wastewater as sludge, reported by the EPA (2017) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2015, to obtain a community-specific value for nitrogen removed in domestic wastewater effluent.

Activity Data – Organic Content in Wastewater (Chemical Oxygen Demand)

Calculating emissions from industrial wastewater requires community-specific datasets on chemical oxygen demand (COD) in wastewater flow per unit of production. These data can be very uncertain, as some industries might use different wastewater throughputs and handling procedures. It is therefore difficult to use the limited national data provided in EPA (2017) and scale to produce community-specific values. As a result, emissions from industrial wastewater are not estimated.

Activity Data – Protein Consumption

A nationwide kg/person-year protein consumption value for the years 1990, 2000, 2005, and 2011-2015 has been provided by the EPA (2017). The 2016 national value of 34.5 kg/person is used in this methodology. In the absence of local protein consumption rates, the national value of 34.5 kg/person is assumed to be a reliable community-specific estimate.

Emission Factor – Methane

Domestic wastewater effluent is either discharged to treated systems (wastewater treatment facilities) or untreated systems (stagnant waterbodies). For methane emissions, emission factors for the wastewater subsector are derived from the following equation:

Equation 43

$$EF = B_o * MCF_j * U_i * T_{i.J}$$

Table B73. Data elements and sources

Data Element	Definition	Units	Data Source
EF	The emission factor for each treatment/discharge pathway or handling system utilized within a community.	kg CH_4/kg BOD	Calculated
B_o	Maximum methane producing capacity of the organics present in domestic wastewater under optimal conditions.	kg CH_4/kg BOD	IPCC (2006)
MCF_j	Methane correction factor - The fraction of BOD that will ultimately degrade anaerobically	Unitless	EPA (2017) IPCC (2006)
U_i	The fraction of population in income group i in inventory year	Unitless	Ratcliffe, et.al, 2016)
$T_{i.J}$	The degree of utilization of treatment/discharge pathway (septic, sewer, latrine, other) of system j for each income group fraction i in inventory year	Unitless	U.S Census (2016)

In the absence of U.S-specific data on $B_{0,}$ the maximum CH_4 producing capacity value of 0.6 kg CH_4/kg BOD is obtained from the IPCC 2006 guidelines.

Community-specific methane correction factors are based on estimates of U_i and $T_{i,j}$. The IPCC (2006) identifies specific utilization rates ($T_{i,j}$) based on the population between development levels, to assign income fractions (U_i). To define the rural/urban spread, referred is Ratclifffe et. al, (2016) American

Community Survey and Geography Brief—the lowest level of disaggregation available—which identifies an 86% and 14% urban-rural divide in the United States based on number of counties surveyed. Hence, assigned "urban" utilization rates are 0.95 (sewer) and 0.05 (septic) for the 86% urban population based on IPCC, 2006 guidance. For the remaining 14% of communities, "rural" utilization rates of 0.9 (septic), 0.02 (latrine), and 0.08 (sewer) are assigned (IPCC, 2006).

The selected methane correction factors (MCF), which represents the fraction of BOD that will ultimately degrade anaerobically, are dependent on the treatment system used – either sewer, septic, or latrine. Used are IPCC (2006) MCF values, seen below in Table B74.

Table B74. IPCC (2006) MCF values used in this methodology

Treatment Type and discharge pathway or system	MCF (Unitless)
Centralized aerobic treatment plant (well-managed)	0
Septic system	0.5
Latrine (small family)	0.1

Source: IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 6: Wastewater Treatment and Discharge, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

Emission Factor – Nitrous Oxide

An emission factor for N_2O emissions from discharge to wastewater is not developed for the United States, hence, this methodology relies on the default IPCC (2006) value, 0.005 kg N_2O-N/kg sewage-N produced, is used (EPA, 2017).

General Assumptions & Limitations

Activity Data

- BOD levels are taken from national datasets (EPA, 2017). These national values are assumed to be applicable at a community level.
- Since it is unknown where communities send their wastewater effluent for treatment, all emissions under this subsector are assigned as scope 3. It. Communities with wastewater treatment facilities located within their boundary can choose to fold these scope 3 emissions into their scope 1 reported estimates or allocate accordingly with neighboring communities.
- Estimations used for assigning development level fractions and degree of utilization proportions were taken from Radcliffe et. al, (2016) Community-level estimates were assumed to be akin to the national values and thus used in this methodology.

Emission Factors

- In the absence of methane recovery datasets, methane recovery at a community level cannot be estimated.
- The EPA (2017) reports that IPCC's MCF values of 0 for centrally treated well-managed aerobic treatment systems and 0.5 for septic systems are best used for estimating wastewater emissions. As such, this methodology relies these same MCF values.

References:

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Chapter 6: Wastewater Treatment and Discharge, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

The report provides the range of methane correction factors for domestic wastewater based on the type of treatment and discharge pathway or system.

Ratcliffe, M., Burd, C., Holder, K., & Fields, A. (2016). Defining rural at the US Census Bureau. American community survey and geography brief, 1-8. Available online at https://www2.census.gov/geo/pdfs/reference/ua/Defining_Rural.pdf

This report identifies the development fraction that exist on a county level and how they relate to the total population.

U.S. Census Bureau (2016). City and Town Population Totals. Retrieved December 21st, 2017 from https://www.census.gov/data/tables/2016/demo/popest/total-cities-and-towns.html

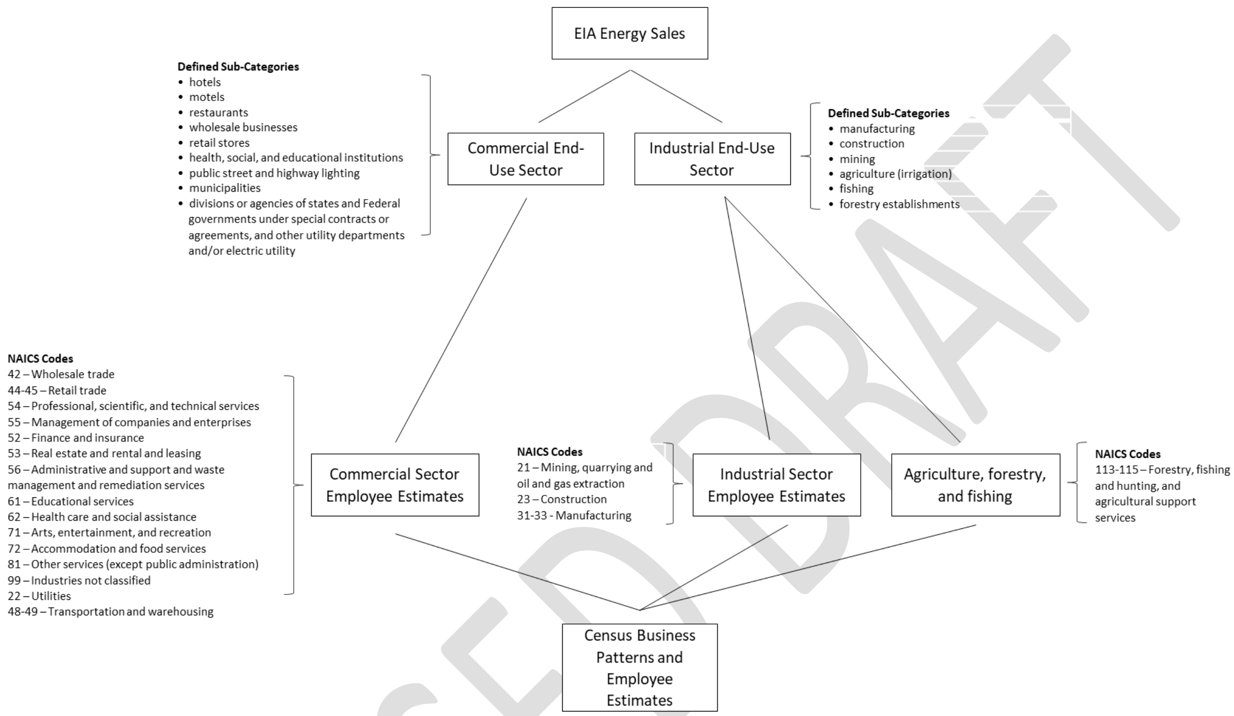
The website provides annual statistics on population demography in U.S states, cities, and towns.

U.S. Environmental Protection Agency (2017) Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2015 EPA 430-P-17-001 US Environmental Protection Agency, Washington, DC. Available online at https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report

The report provides total BOD produced in the U.S for 1990 through 2015; methane correction factors for various treatment systems; protein consumed for 1990 through 2015; and percent of COD entering treatment facilities, U.S population served by wastewater treatment plants, and nitrogen removed as sludge for 1990 through 2015.

Appendix C – Mapping of Commercial and Industrial Input and Disaggregation Data

Figure C1. Mapping of Commercial and Industrial Input and Disaggregation Data



Appendix D – Industry Categories

Table D1. Industry categories used to produce industrial sector employee estimates by NAICS ID.

Census *Business Patterns* Categories Included in Industrial Sector Employee Estimates	
NAICS ID	**NAICS ID Description**
21	Mining, quarrying, and oil and gas extraction
23	Construction
31-33	Manufacturing

Census *Business Patterns* Categories Excluded from Industrial Sector Employee Estimates	
NAICS ID	**NAICS ID Description**
42	Wholesale trade
44-45	Retail trade
54	Professional, scientific, and technical services
55	Management of companies and enterprises
51	Information
52	Finance and insurance
53	Real estate and rental and leasing
56	Administrative and support and waste management and remediation services
61	Educational services
62	Health care and social assistance
71	Arts, entertainment, and recreation
72	Accommodation and food services
81	Other services (except public administration)
99	Industries not classified
22	Utilities
48-49	Transportation and warehousing

Source: U.S. Census Bureau. 2017. (Database) CBP Datasets - 2015: Complete ZIP Code Industry Detail File; Complete ZIP Code Totals File. Released 4/20/17. https://www.census.gov/data/datasets/2015/econ/cbp/2015-cbp.html

Table D2. Industry categories within the industrial end-use sector

Industry Category End-Users
manufacturing
construction
mining
agriculture (irrigation)
fishing
forestry establishments

Source: EIA. (2017). Form EIA-861 detailed data files. Sales to Ultimate Customers. Release date: 11/6/17. Retrieved from: https://www.eia.gov/electricity/data/eia861/

Appendix E – U.S. Regional Grid Electricity Emission Factors

U.S. Regional Electricity Grid	Carbon Dioxide (CO_2) (kg/MJ)	Methane (CH_4) (kg/MJ)	Nitrous Oxide (N_2O) (kg/MJ)
AKGD	0.135105556	9.6944E-06	1.3889E-06
AKMS	0.063394444	2.8889E-06	0.0000005
AZNM	0.131497222	9.9444E-06	0.0000015
CAMX	0.066511111	4.1667E-06	0.0000005
ERCT	0.127152778	9.5833E-06	1.3889E-06
FRCC	0.127472222	9.4444E-06	0.00000125
HIMS	0.145152778	1.1972E-05	1.8889E-06
HIOA	0.209522222	2.2806E-05	3.5278E-06
MROE	0.210194444	1.9667E-05	3.2778E-06
MROW	0.156088889	0.0000145	2.5278E-06
NEWE	0.070327778	1.1333E-05	0.0000015
NWPP	0.08205	7.6944E-06	1.1389E-06
NYCW	0.080111111	2.7778E-06	3.889E-07
NYLI	0.148466667	1.5889E-05	2.0278E-06
NYUP	0.037127778	2.6389E-06	3.889E-07
RFCE	0.095530556	6.3056E-06	1.1389E-06
RFCM	0.160277778	8.4444E-06	2.2778E-06
RFCW	0.156672222	1.3611E-05	2.3889E-06
RMPA	0.172338889	0.00001725	2.5278E-06
SPNO	0.177955556	1.8778E-05	2.7778E-06
SPSO	0.157288889	1.1972E-05	1.8889E-06
SRMV	0.1057	6.3056E-06	8.889E-07
SRMW	0.203186111	1.0333E-05	3.2778E-06
SRSO	0.137261111	1.0972E-05	1.6389E-06
SRTV	0.149363889	1.1722E-05	2.1389E-06
SRVC	0.101463889	8.4444E-06	1.3889E-06

Source: U.S. Environmental Protection Agency. 2018. Emissions & Generation Resource Integrated Database (eGRID) 2016. Retrieved from: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Endnotes

[1] The Global Covenant of Mayors formally brought together the Covenant of Mayors and the Compact of Mayors, the world's two primary initiatives of cities and local governments, to advance their transition to a low emission and climate resilient economy.

[2] At the time of this work, the 2019 amendments to the 2006 IPCC guidelines did not exist, and therefore were not considered.

[3] For the purposes of this methodology, households correspond to all categories of "housing units" as defined in the U.S. Census American Community Survey (ACS), including single family units, apartments in multi-unit buildings, etc.

[4] "Census Places" are defined by the census bureau as either a) incorporated places, which are legal areas that provide governmental functions for a concentration of people and correspond to villages, towns, and cities or b) census designated places, which are statistical areas delineated to provide data for a settled community, or concentration of population, identifiable by name but not legally incorporated. (Source: https://www.census.gov/geo/reference/webatlas/places.html)

[5] The EIA defines distillate fuel oil as a general classification for one of the petroleum fractions produced in conventional distillation operations. The category includes diesel fuels and fuel oils.

[6] The EIA defines kerosene as light petroleum distillate that is used in space heaters, cook stoves, and water heaters and is suitable for use as a light source when burned in wick-fed lamps.

[7] EIA 861 part A refers to electricity sales where energy and delivery are bundled. Where energy and delivery are unbundled, part B refers to energy sales and part C refers to delivery sales. Part B is excluded from final sales totals to avoid double counting.

[8] These figures represent an average of the emission factors for Distillate Fuel Oil Numbers 1, 2, and 4 published in (EPA, 2015).

[9] "Places" are defined by the census bureau as either a) incorporated places, which are legal areas that provide governmental functions for a concentration of people and correspond to villages, towns, and cities or b) census designated places, which are statistical areas delineated to provide data for a settled community, or concentration of population, identifiable by name but not legally incorporated. (Source: https://www.census.gov/geo/reference/webatlas/places.html)

[10] These figures represent an average of the emission factors for Distillate Fuel Oil Numbers 1, 2, and 4 published in (EPA, 2015).

[11] The EIA defines distillate fuel oil as a general classification for one of the petroleum fractions produced in conventional distillation operations. The category includes diesel fuels and fuel oils. Products known as No. 1, No. 2, and No. 4 diesel fuel are used in on-highway diesel engines, such as those in trucks and automobiles, as well as off-highway engines, such as those in railroad locomotives and agricultural machinery. Products known as No. 1, No. 2, and No. 4 fuel oils are used primarily for space heating and electric power generation.

[12] The EIA defines residual fuel oil as the topped crude of refinery operations, which includes No. 5 and No. 6 fuel oils, as defined in ASTM Specification D 396 and Federal Specification, VV-F-815C; Navy Special fuel oil as defined in Military Specification MIL-F-859E including Amendment 2 (NATO symbol F-77); and Bunker C fuel oil. Residual fuel oil is used for the production of electric power, space heating, vessel bunkering, and various industrial purposes.

[13] The EIA defines kerosene as light petroleum distillate that is used in space heaters, cook stoves, and water heaters and is suitable for use as a light source when burned in wick-fed lamps.

[14] These figures represent an average of the emission factors for Distillate Fuel Oil Numbers 1, 2, and 4 published in (EPA, 2015).

[15] "Farm" is defined by the EIA as an energy-consuming sector that consists of establishments where the primary activity is growing crops and/or raising animals. Energy use by all facilities and equipment at these establishments is included, whether or not it is directly associated with growing crops and/or raising animals. Common types of energy-using equipment include tractors, irrigation pumps, crop dryers, smudge pots, and milking machines. Facility energy use encompasses all structures at the establishment, including the farmhouse.

[16] These figures represent an average of the emission factors for Distillate Fuel Oil Numbers 1, 2, and 4 published in (EPA, 2015).

[17] BTS collects data from certificated U.S. air carriers and any foreign air carrier that has at least one point of service in the United States. A certificated air carrier is one that holds a Certificate of Public Convenience and Necessity, by the U.S. Department of Transportation, that authorizes the carrier to engage in air transportation.

[18] While the flaring of landfill gas is typically reported under the waste sector, to burning of landfill gas for energy purposes is reported under the stationary energy sector

[19] Similar to above, the burning of waste for non-energy purposes falls under the waste sector, whereas any waste burned for energy (e.g. heat or electricity generation) falls under the stationary energy sector

[20] The exact number of active and closed industrial waste landfills in the United States is unknown (EPA, 2017)

[21] Our inventory applies Environmental Protection Agency's method for the national inventory (multiplying a per capita estimate by population) to the local community level. This method is less accurate when applied to the community-scale since there will be variations across communities that average out nationally. However, this method is the best to apply with the existing data that is available