City of New Haven
Toni N. Harp, Mayor

# City of New Haven Greenhouse Gas Inventory, 2015

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Prepared by

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# Contents

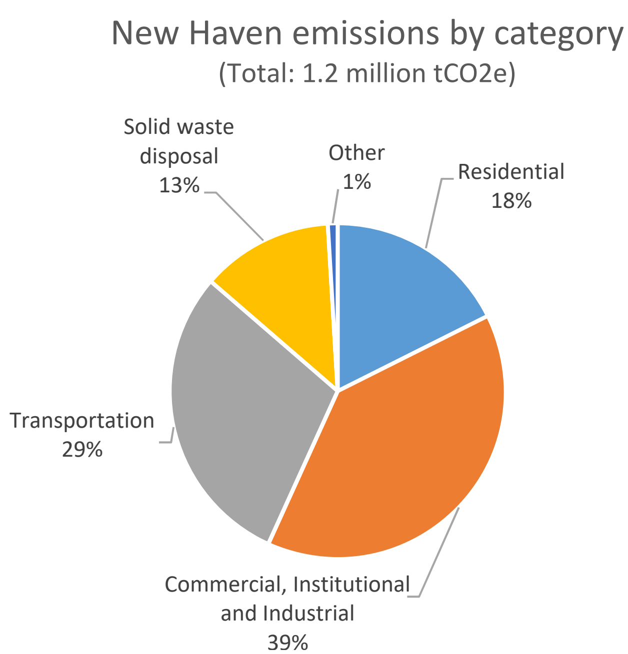
The Yale Roosevelt Institute Center for Energy and Environment commenced the data collection for this Inventory in Fall 2016.

# Executive Summary

In January 2017, Mayor Toni Harp signed the City of New Haven onto the Compact of Mayors (now known as the Global Covenant of Mayors)– an international alliance of cities and local governments promoting voluntary climate action. As part of this Covenant, cities report their greenhouse gas emissions and strategies for reduction in order to foster collaboration in climate change mitigation and adaptation. In this inventory, New Haven is reporting its 2015 emissions in compliance with the BASIC requirements of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). This protocol was developed by the World Resources Institute, C40 Cities Climate Leadership Group, and ICLEI – Local Governments for Sustainability and is required as part of the compliance with the Global Covenant of Mayors. This is the third greenhouse gas (GHG) inventory performed for the City of New Haven; the first was performed in 2001, estimating 1999 emissions and the second was completed in 2011, estimating 2009 emissions.

Over the past couple decades, our understanding of GHGs, their sources, and reporting methodologies have developed substantially. As such, this inventory includes more sources of pollution and uses different estimations of the Global Warming Potential (GWP) of $CH_4$ (methane) and $N_2O$ (nitrous oxide) than used in the past inventories. In addition, standard emission factors have also changed substantially over the years, reflecting not only cleaner technology but also a greater understanding of emission sources. Thus, these inventories should be considered as estimates or snapshots; we can compare them, but with their discrepancies in mind. While the City of New Haven and the community have been working to reduce our climate footprint, it is not at all clear – due to the above reasons – whether the decrease is as great as estimated below.[1]

In 2015, New Haven emitted 1.21 million metric tons of $CO_2$e, which represents a 22% decline in emissions from 2009. Additionally, New Haven's population grew since 2009, but per capita emissions declined by 26%, and are about 6.7 tonnes/capita lower than the national average of 16 tonnes per person. Overall emissions and emissions per capita have been decreasing since 1999 (Figure S1). Commercial, institutional and industrial



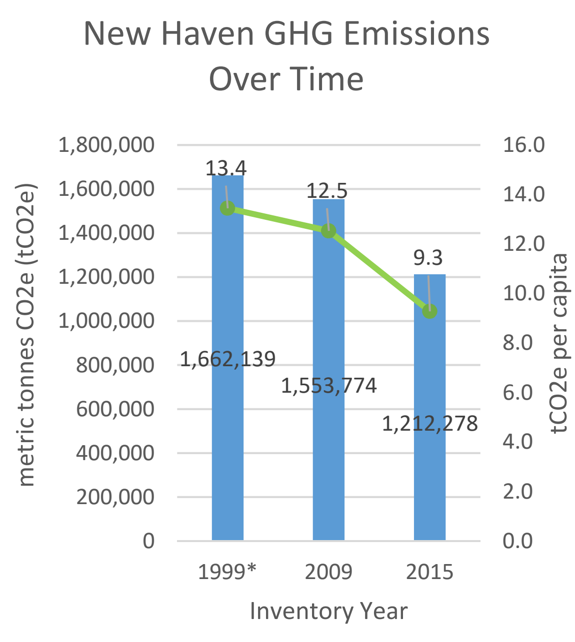




*Figure S1. New Haven GHG emissions by category and change over time.*

[1] Please see the section, "Methodology, Uncertainty, and Potential Areas for Inventory Improvement" for an in-depth review of the discrepancies among this inventory and its previous iterations.

sources produced the most greenhouse gases (39% of total) followed by transportation (29%) and residential sources (18%).[2]

*Table S1. 2015 New Haven GHG Emissions by Category*

| Category | Emissions $tCO_2e$) |
|---|---|
| Residential | 213,318 |
| Commercial, institutional and industrial | 475,042 |
| Transportation | 358,517 |
| Solid waste disposal | 153,911 |
| Other | 11,492 |
| **TOTAL** | **1,212,280** |

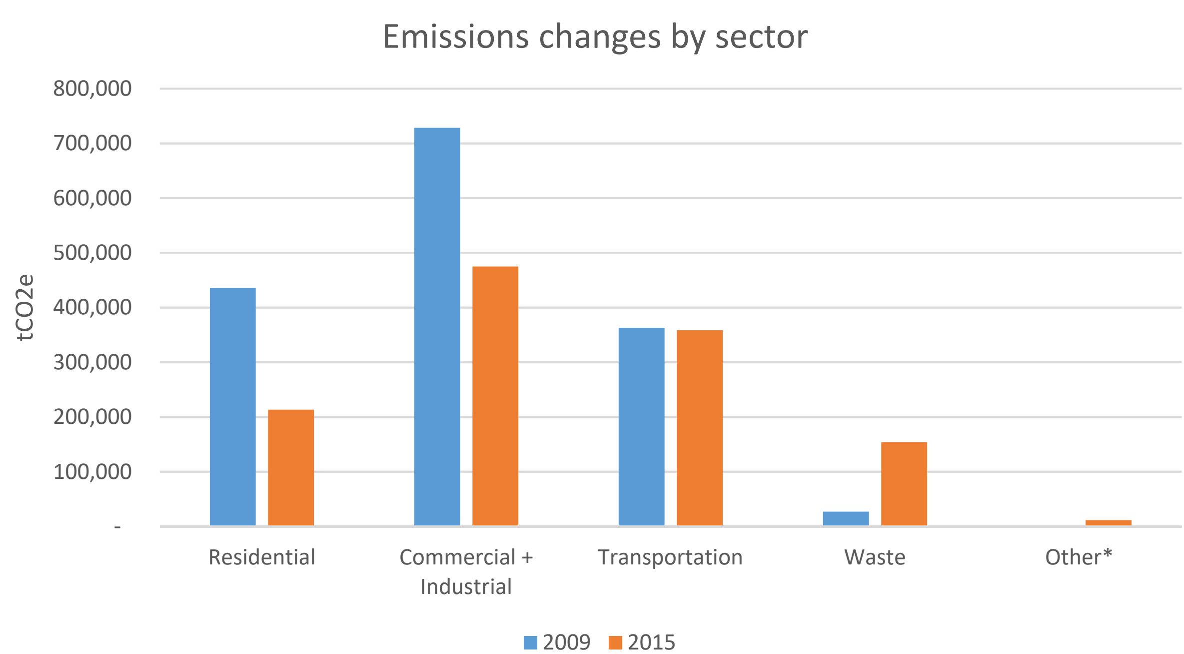



*Figure S2. GHG emissions changes by sector from 2009 to 2015.*

** Categories counted as "Other" in 2015 are counted as "Commercial/Institutional/Industrial" in 2009.*
*Sector emission changes across time depicted here sometimes reflect the nature of calculation or data availability. Please see section: Methodology, Uncertainty, and Potential Areas for Inventory Improvement.*

[2] Note: many factors in calculating GHG emissions have changed since the previous inventory. See "Notes on data and calculation quality" for more details.

## Sector emissions breakdowns

### Residential

Overall emissions from the residential sector in 2015 are estimated to be 213,316 $tCO_2e$, a decrease from 2009 (435,426 $tCO_2e$).[3] The majority of the residential sector's emissions is from heating fuel and electricity consumption.

*Table S2. Summary of residential emissions.*

| Source | tCO2e |
|---|---|
| Electricity | 80,638 |
| Natural gas | 52,214 |
| LPG[4] | 7,063 |
| Heating oil (6% biodiesel) | 73,008 |
| Wood | 395 |
| **TOTAL** | **213,316** |

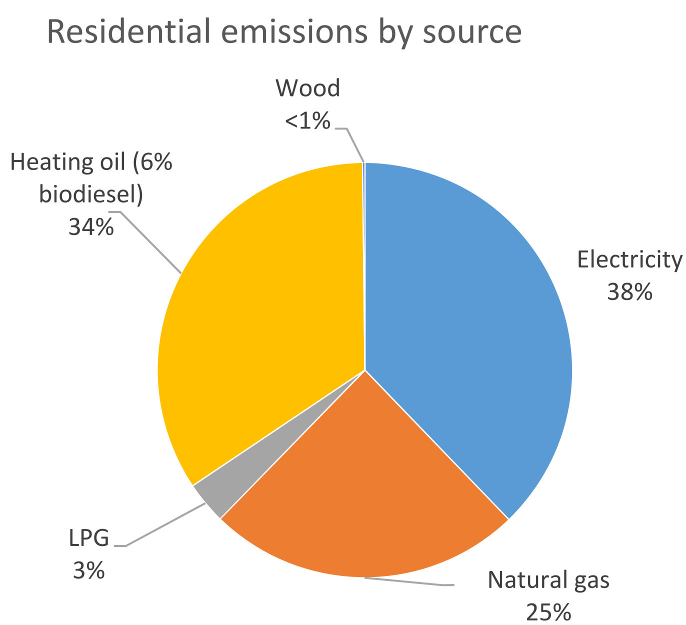



*Figure S3. Residential emissions by source.*

[3] This decrease largely reflects an unexplained drop in residential electricity consumption (see "Notes on data quality and interpretation" section – 4b) and may not reflect actual changes in residential emissions.

[4] LPG = Liquified Propane Gas

## Commercial, institutional and industrial

Total emissions from the commercial, institutional (which includes City of New Haven government) and industrial sector in 2015 were 475,042 $tCO_2e$. The main contributors to these emissions are electricity and natural gas consumption[5]. The emissions of this sector have decreased by 34.8% from 2009 (728,370 $tCO_2e$).

*Table S3. Summary of commercial, institutional and industrial emissions*

| Source | tCO2e |
|---|---:|
| Electricity | 210,890 |
| Natural gas | 71,694 |
| LPG | 6,670 |
| No.2 distillate fuel oil | 32,633 |
| Construction fuel | 7,955 |
| Residual heating oil | 487 |
| Yale Power Plants (natural gas) | 144,713 |
| **TOTAL** | **475,042** |

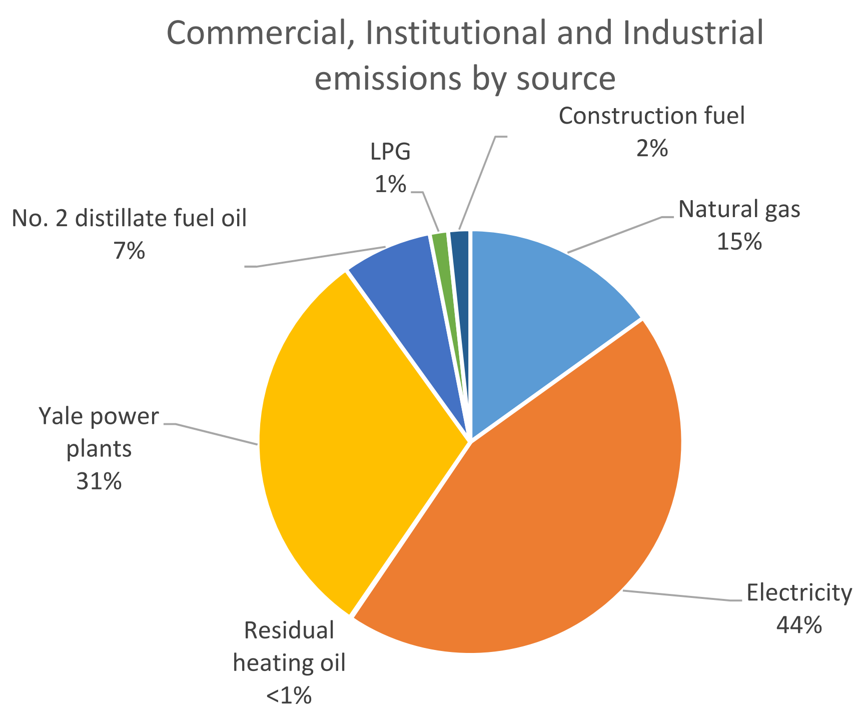



*Figure S4. Commercial, Institutional and Industrial emissions by source*

[5] Yale power plants running on natural gas to supply both electricity and heating to the campus.

## Transportation

Emissions from New Haven in-boundary transportation in 2015 totaled 358,517 $tCO_2e$ – displaying 1.2% decrease from 2009 (362,883 $tCO_2e$) despite addition of both waterborne and rail emissions. The vast majority of emissions are from on-road transportation (Figure S5). Of on-road transportation, internal combustion engine automobiles running on either gas or diesel were the largest emissions source, followed by heavy-duty vehicles and lightweight trucks (Figure S6).

*Table S5. Summary of Transportation emissions.*

| **Source** | **$tCO_2e$** |
|---|---|
| gas & diesel car | 213,283 |
| electric car | 114 |
| hybrid electric cars | 3,183 |
| gas & diesel truck | 46,153 |
| hybrid electric and alternative fuel trucks | 154 |
| motorcycle | 736 |
| bus | 1,510 |
| heavy-duty vehicles | 70,937 |
| Subtotal: on-road transportation | 336,068 |
| railway | 12,091 |
| waterborne navigation | 10,358 |
| **TOTAL** | **358,517** |

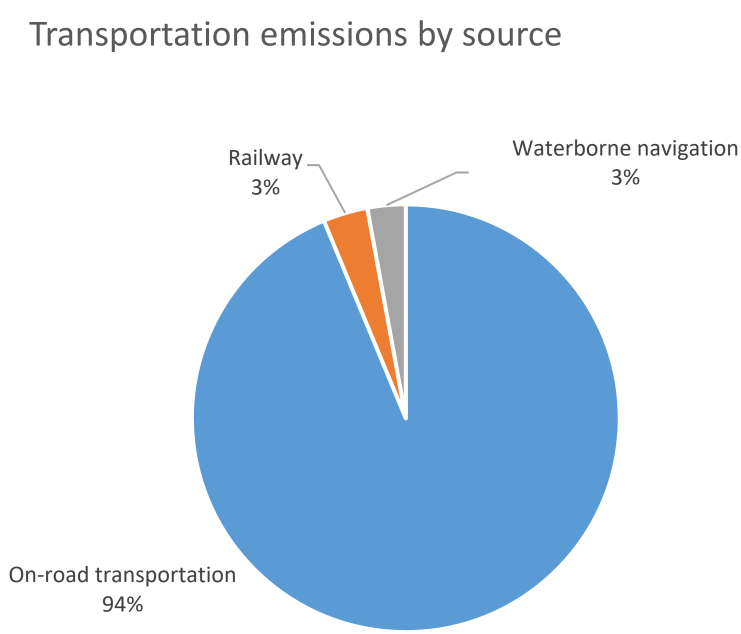



*Figure S5. Transportation emissions by source.*

Emissions from on-road transportation decreased from 1999 to 2009 to 2015 despite calculated yearly vehicle miles travelled increasing between 2009 and 2015 (Table S6), which may reflect a more efficient vehicle fleet[6].

*Table S6. Vehicle miles travelled (VMT) and on-road transportation emissions by year.*

| Year | VMT | $tCO_2e$ | $kgCO_2e$/mile |
|---|---|---|---|
| 1999 | 770,559,530 | 655,681 | 0.85 |
| 2009 | 724,853,500 | 362,883 | 0.50 |
| 2015 | 733,750,740 | 336,068 | 0.46 |

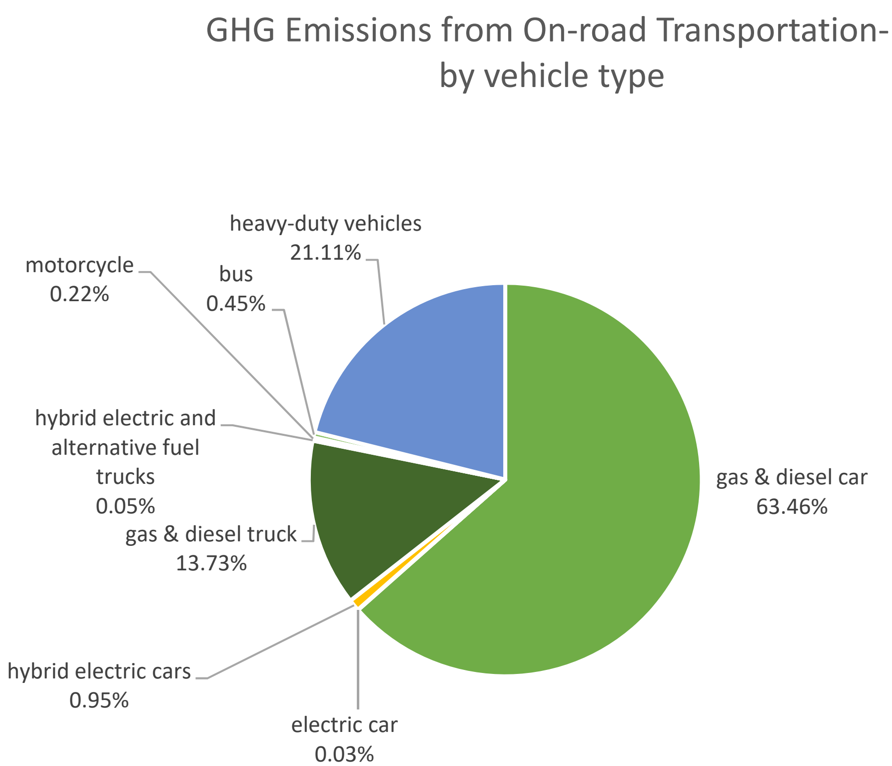



*Figure S6. On-road transportation emissions by vehicle type.*

[6] See notes on data quality and interpretation – Section 5a.

## Solid Waste Disposal

Emissions from solid waste landfilling and incineration accounted for 153,911 metric tonnes of $CO_2e$ in 2015.[7] In 2009, the emissions were calculated to be 27,082 $tCO_2e$.[8] The majority of these emissions comes from municipal solid waste (MSW, or waste produced by residents and small-to-medium-sized businesses) incineration. The rest comes from construction and demolition (C&D) waste landfilling and incineration.

*Table S7. Summary of waste emissions.*

| Source | $tCO_2e$ |
|---|---|
| MSW incineration | 100,934 |
| MSW landfill methane | 3,102 |
| C&D waste incineration | 3,196 |
| C&D waste landfill methane | 46,679 |
| **TOTAL** | **153,911** |

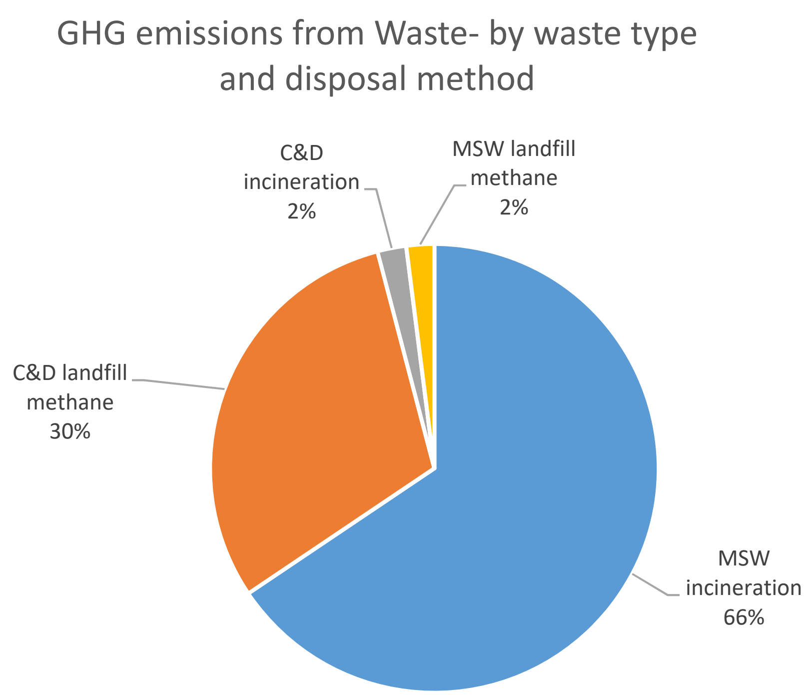



*Figure S7. GHG emissions from Waste- by waste type and disposal method.*

[7] This number is not easily compared to previous years'; see notes on data quality and interpretation Section 3.
[8] The method of calculation for this year differed drastically and included fewer types of waste. See Notes on Data Quality and Interpretation.

As for waste materials, the largest incineration $CO_2$ emissions sources were paper/cardboard (31%), plastics (29%), wood (13%), and food waste (11%) (Figure S8).

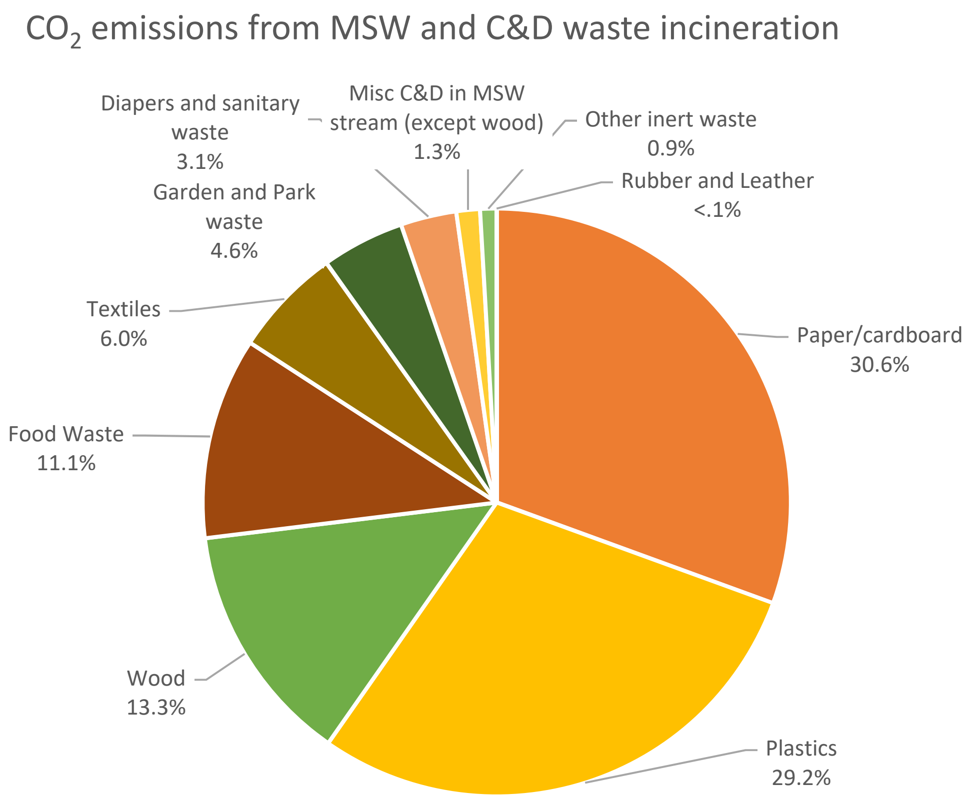



*Figure S8. Carbon dioxide emissions from MSW and C&D waste incineration - breakdown of emissions by material.*

## Other Sources

Four other emissions sources which do not belong to the Residential, Commercial/Institutional/Industrial, Transportation or Solid Waste Disposal categories are summarized here. These sources include the electricity required to treat and pump water and waste water, as well as some unspecified electricity consumption accounts.

*Table S8. Summary of Emissions from Other Sources.*

| Source | $tCO_2e$ |
|---|---|
| "Water, sewage and other" electricity | 2,030 |
| Wastewater treatment | 5,795 |
| Water supply pump | 1,016 |
| "Other" electricity | 2,651 |
| **TOTAL** | **11,492** |

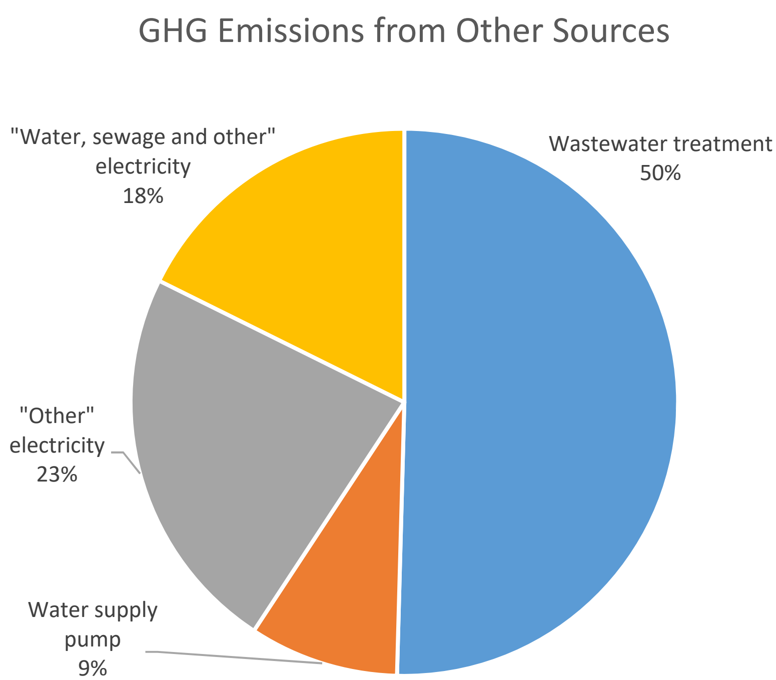



*Figure S9. Percentage of GHG Emissions from Other Sources.*

## Summary table of New Haven GHG emissions - 2015

| Source | Emissions ($tCO_2e$) |
|---|---|
| **Residential** | |
| Electricity | 80,638 |
| Natural gas | 52,214 |
| LPG | 7,063 |
| Heating oil (6% | 73,008 |
| Wood | 395 |
| **TOTAL** | **213,318** |
| **Commercial/Industrial** | |
| LPG | 6,195 |
| No. 2 distillate fuel oil | 29,448 |
| Residual heating oil | 487 |
| Yale power plants | 144,713 |
| Natural gas | 71,694 |
| Electricity | 210,890 |
| LPG - Industrial | 475 |
| No. 2 distillate fuel oil - | 3,185 |
| Construction fuel | 7,955 |
| **TOTAL** | **475,042** |
| **Transportation** | |
| gas & diesel car | 213,283 |
| electric car | 114 |
| hybrid electric cars | 3,183 |
| gas & diesel truck | 46,153 |
| hybrid electric and | 154 |
| motorcycle | 736 |
| bus | 1,510 |
| heavy-duty vehicles | 70,937 |
| diesel trains* | 12,091 |
| waterborne navigation: | 10,358 |
| **TOTAL** | **358,517** |

* (electric included in

| Source | Emissions ($tCO_2e$) |
|---|---|
| **Solid Waste Disposal** | |
| MSW incineration | 100,934 |
| C&D incineration | 3,196 |
| MSW landfilling | 3,102 |
| C&D landfilling | 46,679 |
| **TOTAL** | **153,911** |
| **Other** | |
| Wastewater treatment | 5,795 |
| water pump | 1,016 |
| "Other" electricity | 2,651 |
| "Water, sewage and other" electricity | 2,030 |
| **TOTAL** | **11,492** |

**OVERALL**

| Category | Emissions |
|---|---|
| Residential | 213,318 |
| Commercial, Institutional and Industrial | 475,042 |
| Transportation | 358,517 |
| Solid waste disposal | 153,911 |
| Other | 11,492 |
| **TOTAL** | **1,212,281** |

**$tCO_2e$**

## Methodology, Uncertainty, and Potential Areas for Inventory Improvement

1. Global warming potential of $NO_2$ and $CH_4$: The accepted global warming potential, or GWP, of these greenhouse gases has changed over the past couple decades. Thus, the GWPs differ between 1999, 2009 and now. For the 2009 inventory, Global warming potential (GWP) factors are used from the IPCC 2AR 100 year GWP values ($N_2O$ GWP = 310, $CH_4$ GWP = 21). In the 2015 inventory, IPCC 5AR values – the most current – are used: $N_2O$ GWP = 265, $CH_4$ GWP = 28.
2. Emissions factors discrepancies: In general, emissions factors for diverse fuels or activities may have changed between inventory years. See Appendix A for a list of EPA Emissions Factors.
3. Waste: Many factors – including emission factors for materials in either incineration or landfilling or both, and completeness of information on waste destination – may differ between calculation of 2009 and 2015 waste GHG emissions.
    a. In 1999, only methane emissions were estimated for municipal solid waste, as all was assumed landfilled.
    b. In 2009, the calculation method accounted for incineration vs. waste but may not include biogenic $CO_2$, as 2015 emissions estimations do. While in GPC BASIC reporting, biogenic $CO_2$ emissions (carbon emissions from organic materials such as food waste and paper) are not included in a city's emission total, we include them. These materials are waste which wasn't diverted to compost or recycling and instead was released into the atmosphere as greenhouse gas.
    c. Data on CT waste composition is applied to New Haven MSW, though this may not be truly representative. Thus, some changes in waste emissions may only reflect changing statewide waste stream composition. Finally, the characteristics of some destination RRFs' incinerators were estimated conservatively, which may inflate actual emissions values.
    d. In addition, Construction and Demolition (C&D) waste is included for the first time in the 2015 inventory; we thus expect reported 1999 and 2009 waste emissions numbers were likely low compared to actual emissions.
4. Stationary Energy:
    a. Scope 1 fuel combustion: For residential, commercial, and industrial estimates of LPG consumption, the data is of poor quality as it is prorated from Connecticut consumption. Adjustment for number of households using LPG is made at the residential level, but not for commercial and industrial (this is the same method used in the 2009 inventory). Thus, changes in estimated industrial or commercial LPG may be all or in part due to changes elsewhere in the state.
    b. For reasons not found, residential electricity consumption is 1/3 what was reported in 2009. This large discrepancy may be due to accounting database system errors. United Illuminating performed major updates to their database system which may have contributed to the difference in consumption between years. This is not anticipated to be a reoccurring issue.
    c. Construction inclusion: 2015 is the first year that emissions from construction activity are estimated. In addition, these emissions are estimated based off permitting records and loose estimations of equipment used, and do not estimate $N_2O$ or $CH_4$ emissions due to lack of data. Future iterations of this inventory would benefit from preparation in which companies are surveyed to information on machine and fuel usage per type of project.
    d. Scope 2 electricity: emissions per kWh: For 2010 calculations, the *ISO 2008 New England Electric Generator Air Emissions Report*'s emissions factor of 890 lbs. $CO_2$/MWh was used for $CO_2$ while the most recent emissions factor data for $CH_4$ and $N_2O$ were taken from the EPA eGrid 2007 V1.1[9] for the NEWE New England regional power pool emissions in the year 2005: $N_2O$ (.01701 lbs./MWh) and $CH_4$ (.08649 lbs./MWh).

[9] (http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html)

e. In 2015 calculations, the most recent emissions factor data for all three gases were obtained from the EPA eGrid 2014 v2 for the NEWE New England regional power pool emissions in the year 2014: 570.9 lb/MWh $CO_2$, 96.003 lb/GWh $CH_4$, and 12.843 lb/MWh $N_2O$.
    i. It is important to note that these emission factors come from regional characteristics of the electricity grid. In the case of Connecticut, the regional breakdown of energy sources does not exactly match those in CT. Thus, changes in electricity emissions must be approached with caution as they may in part reflect regional changes.

5. Transportation: The main discrepancy in emissions reporting between previous inventory years and 2015 is that the 2015 GHG Inventory includes new sources (rail activity and marine activity within the harbor). Reported GHG emissions in the 1999 and 2009 inventory years were likely low compared to actual emissions.
    a. Two additional factors weaken the strength of comparison between years of on-road transportation emissions: fleet makeup and VMT surveying. Fleet makeup is estimated using low-quality (nation-level) data in the case of light-weight vehicles; in the case of heavy vehicles, broad assumptions of fuel type are made. Where New Haven lightweight vehicle fleets do not match national fleets, there is discrepancy. In addition, in New Haven, many important improvement to buses especially have been made over the years, but little data exists on alternative fuel buses and other heavy weight vehicles. This positive change may thus be masked by the broad fuel and mileage assumption. Secondly, New Haven VMT are estimated in a one-day sample, which may not be representative or near the mean day out of the year.
    b. Rail emissions from Shoreline East are estimated from 2001 fuel usage data and information on presence in New Haven and prorated to 2017 activity. In addition, we are aware that most locomotives have experienced turnover to presumably more efficient engines. Thus, these emissions numbers must also be interpreted with caution.
    c. Rail emissions do not include activity of cargo trains which operate in the vicinity of the New Haven Port. These trains are known to haul waste and other goods, and including their emissions in subsequent reports would result in a more accurate representation of commerce's share of New Haven emissions.
    d. Emissions from waterborne navigation are from low-quality data (i.e. another city, New York) and prorated based off of commercial activity (by tons of import and export). Subsequent iterations of this inventory would do well to perform surveys in the interim to produce more accurate estimates for this sector's emissions.

## Key to reading

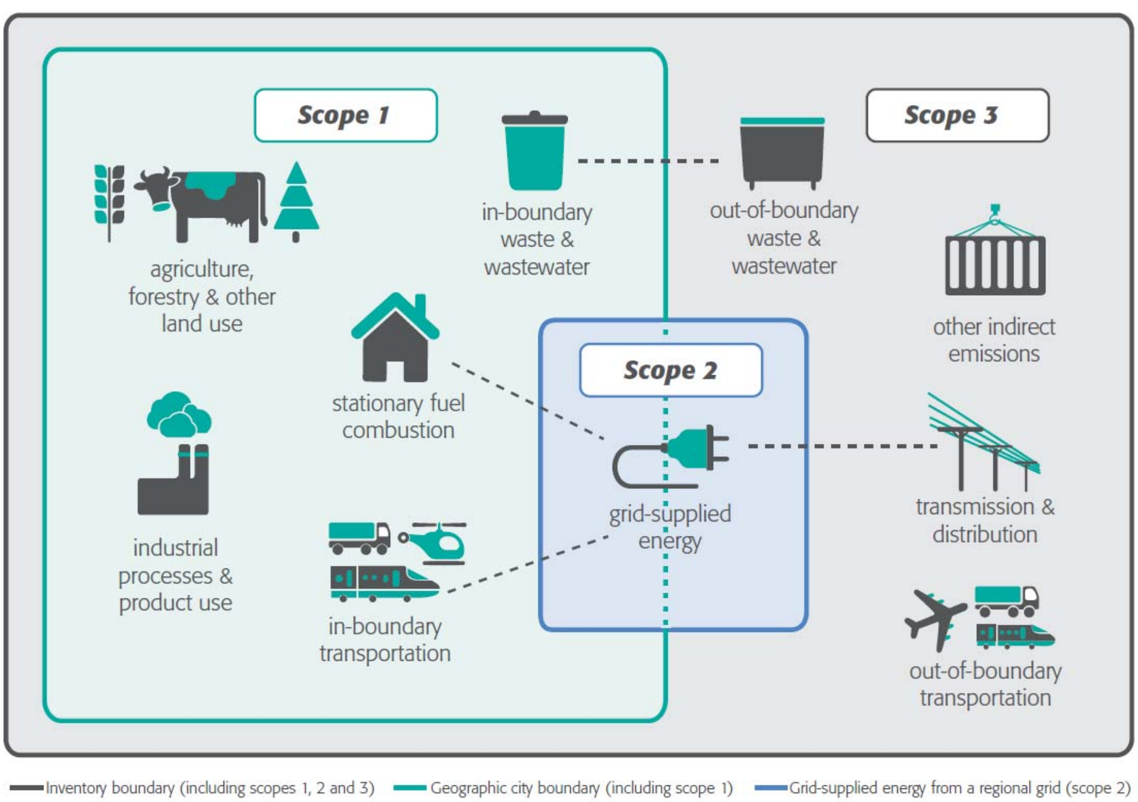
The following document is structured according to the Excel Macro reporting tool which corresponds to the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). The tool is often referred to in this report as the GPC reporting tool. This tool was provided by CDP- a global reporting platform utilized by members of the Global Covenant of Mayors. New Haven is reporting according to the BASIC reporting standards outlined by in the GPC protocol.

For ease of reference, sections of the report are labelled in accordance with the labels used in the GPC protocol. The labels are formatted according to the following hierarchy:

[Major category number].[Subcategory number].[Scope number]

For example: II.1.1 is the code for **II** – Transportation, II.**1** – On-road transportation, II.1.**1** – scope 1.

While the inclusion of these numbers is largely for reference to the GPC protocol, the scope number is relevant to any reader. GHG emissions are broken into scopes to prevent double-counting emissions and to classify how much control an organization has over the production of a particular GHG source. There are 3 scope categories. Scope 1 emissions are referred to as Direct GHG and are defined as 'emissions from sources that are owned or controlled by the organization'. Scope 2 emissions are referred to as Energy Indirect GHG and are defined as 'emissions from the consumption of purchased electricity, steam, or other sources of energy generated upstream from the organization'. Scope 3 emissions are referred to as Other Indirect GHG and are defined as 'emissions that are a consequence of the operations of an organization, but are not directly owned or controlled by the organization'. The diagram in Figure XX from the GPC depicts the types of emissions accounted for under each scope.[10]




[10] Image from the full *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* document, p32.

Any emissions subcategory which does not occur in New Haven will simply not be included, meaning "gaps" in GPC subcategory and scope numbers will be observed among consecutive reporting sections.

All emissions are reported in metric tonnes of carbon dioxide equivalent: $tCO_2e$.

# I – Stationary Energy

## I.1 Residential Buildings

### I.1.1 Emissions from fuel combustion within the city boundary[11]

*Liquefied petroleum gases (LPG)*

According to the United States Energy Information Association, Connecticut's residential LPG consumption was 7.0 trillion Btu. Calculating from numbers of occupied housing units estimated by the American Community Survey (ACS) (above), New Haven households are 3.8% of CT housing units. Using a correction factor of $\frac{1.5}{3.5}$, and assuming per-household LPG consumption is uniform across the state, New Haven residential LPG consumption in 2015 is estimated to amount to:

$$7{,}000{,}000{,}000{,}000 * \frac{1.5}{3.5} * .038 = 114{,}000 \text{ Mmbtu (million btu)}.$$

This increase from the 2008 figures reflects largely the increase in estimated total CT consumption. EPA Emission factors[12] were used for conversion to within the GPC reporting tool, resulting in an emission estimate of 7,063 $tCO_2e$ for New Haven 2015 residential LPG consumption.

*Table SE1. Calculating New Haven residential LPG consumption.*

| | LPG residential consumption | % households using LPG[13] | Number of occupied housing units[14] |
|---|---|---|---|
| Connecticut | 7.0 trillion btu[15] | 3.5% | 1,491,786 |
| New Haven | 114,000 Mmbtu (*Calculated)* | 1.5% | 56,673 |

*Natural gas*

Residential natural gas consumption in 2015 and 2016 was provided by Ted Novicki from United Illuminating.[16][17] From correspondence with United Illuminating, it became clear that 2016 values were more representative of 2015 activity than 2015 values, due to a change-over in the electronic accounts system.

[11] (Appendix B p.11) "Residential fuel consumption" Excel document.
[12] (Appendix A) "Emission Factors for Greenhouse Gas Inventories" by the U.S. EPA (2014).
[13] "Selected Housing Characteristics – 2011-2015 American Community Survey 5-Year Estimates". U.S. Census Bureau. *American Fact Finder*. File: "ACS_15_5YR estimates New Haven city CT" pdf. The estimate is of percent households using bottled, tank, or LP gas, but it was necessary to pool these gases together to estimate a correction factor.
[14] American Community Survey 2015 5-year Estimates. See above.
[15] (Appendix B p.12) U.S. Energy Information Association: *Table F12: Liquefied Petroleum Gases Consumption Estimates, 2015*. File: "LPG CT use from EIA" https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_use_lg.html&sid=US
[16] ted.novicki@uinet.com
[17] Appendix B p.13. "NH electricity consumption 2015 2016" Excel file.

Consumption in cubic feet – 9,581,389 ccf from 39,615 accounts – was converted within the GPC Reporting Tool using an EPA emission factor[18]. Overall, natural gas consumption in New Haven emitted an estimated 52,214 $tCO_2e$ (metric tonnes of carbon dioxide equivalent) in 2015.

### *Heating oil*

An average per-household 6% biodiesel heating oil consumption of 800 gallons/year[19] was multiplied by number of households estimated to burn heating oil. This number was then split into gallons of its component fuels: distillate fuel oil (no.2) and biodiesel.

$$800\,\frac{gallons}{household} * 8{,}951\ households^{20} = 7{,}160{,}800\ gallons$$

$$7{,}160{,}800\ gallons * 94\%\ distillate\ fuel\ oil\ no.2 = 6{,}731{,}152\ gallons\ distillate\ fuel\ oil\ no.2$$

$$7{,}160{,}800\ gallons * 6\%\ biodiesel(100\%) = 429{,}648\ gallons\ 100\%\ biodiesel$$

EPA Emissions factors were used for conversion within the GPC Reporting Tool. Overall, heating oil consumption emitted 73,008 $tCO_2e$ in 2015.

### *Wood-burning*

The average Northeast region wood-burning household consumed 41.8 Mmbtu per year in 2009.[21] As this was the most recent data, the consumption rate was applied to New Haven in the year 2015.

In New Haven, of the 49,771 occupied housing units, it is estimated that 0.2% use wood as a heating fuel for an estimated 99 houses that burn wood.[22]

$$99\ \text{houses} * 41.8\,\frac{\text{Mmbtu}}{\text{yr}} = 4{,}161\ \text{Mmbtu}$$ of wood-burning in New Haven in 2015.

Emissions factors for wood-burning come from the EPA Emissions Factors table, and with input into GPC reporting tool, final emissions for residential wood-burning amount to 395 tCO2e.

## I.1.2: Emissions from grid-supplied energy consumed within the city boundary

### *Electricity*

Residential electricity consumption in 2015 was provided by Ted Novicki[23] from United Illuminating.[24] 2015 consumption was used here, as there was no substantial lack of accounts recorded in the electronic system compared to 2016. The 308,133,193 kWh consumed in 2015 were converted within the GPC Reporting Tool

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18 "Emission Factors for Greenhouse Gas Inventories" by the U.S. EPA (2014). Appendix A.
19 800 gallons 6% Biodiesel per household — estimate by Chris Herb at the Independent Connecticut Petroleum Association. (chris@ctema.com)
20 2011-2015 U.S. Census American Community Survey (ACS) 5-Year Estimates. See above.
21 (Appendix B p.15) "Table CE5.2 Household Wood Consumption in the U.S. – Totals and Averages, 2009". U.S. Energy Information Association: https://www.eia.gov/consumption/residential/data/2009/#wood
22 2015 U.S. Census ACS 5-year Estimates - housing unit and wood usage numbers. See above.
23 ted.novicki@uinet.com
24 Appendix B p.14. "NH electricity consumption 2015 2016" Excel file.

using a U.S. EPA eGRID electricity emission factor (the updated 2014 version) .[25] New Haven is in the NEWE region. Residential electricity consumption in 2015 emitted an estimated 80,638 tCO2e.[26]

[25] From United States EPA eGRID 2014 v2. Appendix A: "3. Subregion Output Emission Rates."
[26] For reasons not found, residential electricity consumption is 1/3 what was reported in 2009. This large discrepancy may be due to accounts system errors.

## I.2 Commercial and Institutional Buildings and Facilities

### I.2.1 Emissions from fuel combustion within the city boundary

#### *Natural gas*

Commercial, institutional, and industrial natural gas consumption in 2015 (13,155,995 ccf excluding Yale consumption[27]) was provided by Ted Novicki from United Illuminating. According to the utility, there is no consistent distinction made between industrial and commercial accounts; thus, emissions are reported in aggregate here. Raw consumption data was converted using an EPA emission factor within the GPC Reporting tool. Overall, commercial natural gas consumption emitted 71,694 $CO_2e$ in 2015.

#### *Fuel oil, heavy fuel oil, and LPG28*

Fuel oil consumption estimates for New Haven were prorated from state level data obtained through the U.S. Energy Information Administration data source. Since the specific fuel number categories were not specified in CT consumption estimates provided by the Energy Information Association, an assumption was made of the consumption makeup of these fuels. Fuel oil here refers to distillate no. 2 fuel oil; heavy fuel oil refers to residual fuel oil no.5.

*Table SE2. Calculating commercial consumption of fuel oil, heavy fuel oil and LPG.*

| **Commercial sector 2015** | CT consumption | # CT establishments (2012) [29] | # New Haven establishments[30] | New Haven consumption *(calculated)* | Emissions (CO2e) *(calculated)* |
|---|---|---|---|---|---|
| Fuel oil | 12.6 trillion btu[31] | 73,193 | 2,296 | 395,000 Mmbtu | 29,294 |
| Heavy fuel oil | 0.2 trillion btu[32] | | | 6,270 Mmbtu | 459 |

[27] Total including Yale: 39,309,779 ccf (hundreds of cubic feet). Yale natural gas consumption from UI/SCG: 26,153,784 ccf.
[28] Calculations: Appendix B p.16-17.
[29] "All sectors: Geographic Area Series: Economy-Wide Key Statistics: 2012". 2012 Economic Census of the United States. *American Fact Finder.* See file: "ECN_2012_ CT New Haven firms breakdown.pdf"

- Classifying commercial: Commercial was interpreted as NAICS codes: 42, 44-45, 48-49, 51, 52, 53, 54, 55, 56, 61, 62, 71, 72, 81 (wholesale trade, retail trade, transportation and warehousing, information, finance and insurance, real estate and rental and leasing, professional, scientific and technical services, management of companies and enterprises, administrative and support and waste management and remediation services, educational services, health care and social assistance, arts entertainment and recreation, accommodation and food services, and other services (except public administration)).

[30] 2012 Economic Census of the U.S. See above.
[31] "Table F7: Distillate Fuel Oil consumption estimates, 2015". U.S. Energy Information Administration. State Energy Data 2015: Updates by Energy Source. (Appendix B p.18) (https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_use_df.html&sid=US)
[32](Appendix B p.19) "Table F9: Residual fuel oil consumption estimates, 2015" by the U.S. Energy Information Association.

| | | | | | |
|---|---|---|---|---|---|
| LPG | 3.2 trillion Btu[33] | | | 100,000 Mmbtu | 6,195 |

Connecticut 2015 commercial consumption estimates for LPG, heating oil, and residual heating oil were prorated to New Haven using the fact that 3.14% of CT commercial establishments are found in New Haven:

$$CT\ commercial\ consumption * 3.14\% = New\ Haven\ commercial\ consumption$$

New Haven commercial fuel oil consumption was converted from Mmbtu to gallons[34]: 2,860,000 gallons. Then, consumption estimates for all three fuels were converted within the GPC reporting tool to CO2e using EPA emission factors. See above table for final emissions numbers.

#### *Municipal government fuel oil*

The City of New Haven Bureau of Purchases budget for fuels purchasing in February of 2015 recorded an estimated consumption quantity of 15,000 gallons of no. 2 heating fuel for the year.[35] This consumption estimate was converted using EPA Emissions Factors within the GPC Reporting Tool to 154 $tCO_2e$ in 2015.

#### *Yale University power production*

The total scope 1 emissions from Yale University power plants (Central and Medical) for FY16 are 144,713 $tCO_2e$. This information was provided by Lindsay Crum, LEED Green Associate and Metrics & Program Manager at the Yale Office of Sustainability.[36]

### I.2.2 Emissions from grid-supplied energy consumed within the city boundary

#### *New Haven's water supply pump consumption*

Although the New Haven water pump is not located within the city boundary, it was deemed appropriate to include due to New Haven's direct and specific causation of the pump's electricity consumption. The Southern Connecticut Regional Water Authority provided a 2015 water pump electricity consumption measurement of 3,881,700 kWh.[37] Converted within the GPC Reporting Tool using the EPA eGRID electricity consumption emission factor for New Haven's region[38], this water pump electricity consumption amounted to 1,016 $tCO_2e$ for the year 2015.

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[33] "Table F12: Liquefied Petroleum gases consumption estimates, 2015". U.S. EIA. (Appendix B. p12)
[34] "Emission Factors for Greenhouse Gas Inventories". U.S. EPA (2014). (Appendix A)
[35] "Fuels-Various". *City of New Haven Bureau of Purchases – Summary of Solicitation Results*. Solicitation #21316. (Appendix B p.20)
[36] Correspondence with Lindsay Crum, Sustainability Metrics & Program Manager for the Yale Office of Sustainability
[37] Tiffany Lufkin tlufkin@rwater.com, Amy Velasquez avelasquez@rwater.com
[38] From United States EPA eGRID 2014 v2. (Appendix A): "3. Subregion Output Emission Rates."

### *Commercial and "Water, sewage and other systems"*

United Illuminating provided the 2015 electricity consumption information for Commercial/Institutional/Industrial and "Water, sewage, and other systems" categories. These consumption numbers were converted to CO2e using the EPA eGRID electricity emissions factors by region table, as before, within the GPC Reporting Tool. See resulting emissions estimates below.

*Table SE3. Electricity usage of commercial/institutional/industrial and other accounts.*

| Year | Type | Number electric accounts | kWh | $tCO_2e$ *(Calculated)* |
|---|---|---|---|---|
| 2015 | Commercial/ Institutional/ Industrial | 6867 | 805,849,078 | 210,890 |
| 2015 | Water, sewage and other systems | 26 | 7,758,158 | 2,030 |

## I.3 Manufacturing Industries and Construction

### I.3.1 Emissions from fuel combustion within the city boundary

#### *Natural Gas*

Natural gas consumption of manufacturing industries and construction is included in the Commercial section of this report, as the utility makes no consistent distinction between the two firm types.

#### *Fuel oil, heavy fuel oil, and LPG*[39]

Fuel oil consumption data for New Haven was prorated based on state level data obtained from the U.S. Energy Information Association. Since the specific fuel number categories were not specified in CT consumption estimates provided by the Energy Information Association, an assumption was made of the consumption makeup of these fuels. Fuel oil here refers to distillate no. 2 fuel oil; heavy fuel oil refers to residual fuel oil no.5.

*Table SE4. Calculating industrial fuel oil, heavy fuel oil and LPG consumption.*

| **Industrial sector 2015** | CT consumption | # CT establishments (2012) [40] | # New Haven establishments[41] | New Haven consumption *(calculated)* | Emissions ($tCO_2e$) *(calculated)* |
|---|---|---|---|---|---|
| Fuel oil | 12.6 trillion btu[42] | 4567 | 70 | 42,900 Mmbtu | 3,185 |
| Heavy fuel oil | 0.2 trillion btu[43] | | | 383 Mmbtu | 28 |
| LPG | 3.2 trillion Btu[44] | | | 7,664 Mmbtu | 475 |

Connecticut 2015 industrial consumption estimates for LPG, heating oil, and residual heating oil were prorated to New Haven using the fact that 1.53% of CT industrial establishments are found in New Haven:

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[39] Calculations in Appendix B p.16-17. Excel document: "Commercial Industrial fuel consumption"

[40] "All sectors: Geographic Area Series: Economy-Wide Key Statistics: 2012". 2012 Economic Census of the United States.

- Classifying commercial and industrial: We categorize industrial as NAICS codes 21, 22, and 31-33: Mining, quarrying, and oil and gas extraction, utilities, and manufacturing. Utilities in New Haven were excluded, as their emissions are included in other categories.

[41] 2012 Economic Census of the U.S. See above.

[42] "Table F7: Distillate Fuel Oil consumption estimates, 2015". U.S. EIA. (Appendix B p.18) (https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_use_df.html&sid=US)

[43] "Table F9: Residual fuel oil consumption estimates, 2015". U.S. EIA. (Appendix B p.19)

[44] "Table F12: Liquefied Petroleum gases consumption estimates, 2015". U.S. EIA. (Appendix B p.12)

$$CT\ industrial\ consumption * 1.53\% = New\ Haven\ industrial\ consumption$$

New Haven industrial fuel oil consumption was converted from Mmbtu to gallons[45]: 42,900 Mmbtu is equivalent to 310,990 gallons. Then, all consumption estimates were converted within the GPC reporting tool to CO2 equivalent using EPA emission factors. See above table for final emissions numbers.

#### *Construction diesel fuel*

Buildings permitting data for the entire year of 2015 were obtained from the City of New Haven Buildings Department. Of this data, project categories (new construction requiring foundation or of large enough size, large additions) for which fuel-burning equipment would be needed were counted. For each project category, average duration as well as number and activity of relevant construction equipment were estimated, yielding total hours worked by a number of different machines: backhoe, excavator, dump truck, concrete truck, and crane[46]. Then, using horsepower rating and emission factor estimations from the Federal Emergency Management Agency[47], carbon dioxide emissions from construction activity was calculated. No methane or dinitrogen monoxide emissions factors were included due to lack of availability. The CO2 emission number – 7,955 tCO2 – was recorded directly in GPC Reporting Tool.

### I.3.2 Emissions from grid-supplied energy consumed within the city boundary

Natural gas consumption of manufacturing industries and construction is included in the Commercial section of this report, as the utility makes no distinction between the two firm types.

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45 "Emission Factors for Greenhouse Gas Inventories". U.S. EPA (2014). (Appendix A)
46 Not provided in Appendix. See: "Construction permitting emissions estimation" Excel file.
47 "Calculation sheet – combustible emissions". (Appendix B p.22) Available from the Federal Emergency Management Agency's data library at https://www.fema.gov/media-library-data/20130726-1711-25045-6430/appendix_d.pdf.

## I.6 Non-specified sources

### I.6.2 Emissions from grid-supplied energy consumed within the city boundary

#### *"Other" electricity category*

United Illuminating's 2015 data included an "Other" category, which was responsible for 10,129,173 kWh electricity consumption. Converted within the GPC Reporting Tool using the EPA eGRID regional emission factor, this amounted to 2,651 $tCO_2e$.

# II – Transportation

## II.1 On-road transportation

### II.1.1 Emissions from fuel combustion on-road transportation occurring in the city

2015 New Haven emissions from on-road transportation[48] were calculated using vehicle miles traveled (VMT) data collected by the Connecticut Department of Transportation.[49] CTDOT originally provided a daily VMT per road type (DVMT). From this a yearly VMT per road type (YVMT) was estimated by multiplying by 365. CTDOT also provided a breakdown of vehicle type traffic on each road type. Thus YVMT by each vehicle type was calculated. Single unit heavy duty trucks were combined into one category, as were combination trucks.

*Table T1. New Haven 2015 YVMT by vehicle type and road classification*

| | | Vehicle type | | | | | |
|---|---|---|---|---|---|---|---|
| **Road classification** | **YVMT** | **motorcycles** | **cars** | **pickup trucks/vans** | **bus** | **single units** | **combination trucks** |
| Interstate | 3.39E+08 | 6.45E+05 | 2.69E+08 | 3.84E+07 | 7.46E+05 | 1.02E+07 | 1.98E+07 |
| Other Freeways & Expressways | 6.14E+07 | 2.03E+05 | 5.06E+07 | 7.95E+06 | 6.75E+04 | 1.53E+06 | 1.09E+06 |
| Other Principal Arterial | 1.35E+08 | 1.59E+06 | 1.07E+08 | 2.05E+07 | 1.48E+05 | 2.11E+06 | 3.08E+06 |
| Minor Arterial | 1.31E+08 | 6.42E+05 | 1.09E+08 | 1.68E+07 | 6.55E+04 | 2.00E+06 | 2.17E+06 |
| Major Collector | 4.26E+07 | 2.64E+05 | 3.57E+07 | 5.45E+06 | 2.13E+04 | 5.75E+05 | 5.79E+05 |
| Minor Collector | 6.64E+05 | 3.26E+03 | 5.41E+05 | 1.03E+05 | 2.66E+02 | 7.97E+03 | 9.10E+03 |
| Local System | 2.43E+07 | 2.34E+05 | 1.97E+07 | 3.84E+06 | 1.46E+04 | 3.04E+05 | 2.43E+05 |
| **TOTAL YVMT** | **7.34E+08** | 3.58E+06 | 5.92E+08 | 9.31E+07 | 1.06E+06 | 1.67E+07 | 2.70E+07 |
| **PERCENT** | **100.00%** | 0.49% | 80.73% | 12.69% | 0.15% | 2.28% | 3.68% |

[48]Original data: Appendix C p.24-25
Excel document: "2015_Urban_Percent_breakdown by vehicle type-and-New-Haven-City-Mileage"
Data with calculations: Appendix C p.26-28. Excel Document: "Real VMT data 2015 with calculations")
[49] The data were provided by Facundo Dominguez at Facundo.Dominguez@CT.Gov.

### *Emissions from each vehicle type*

VMT for each vehicle type then allocated to different fuel technologies, detailed below. For each fuel technology-vehicle type combination, amount energy source consumed per distance traveled was estimated. Then, emissions per unit energy source consumed were calculated using various emission factors from EPA Emission Factors for Greenhouse Gas Inventories (Table T10 for emissions factors names and years). Overall, on-road vehicle emissions emitted an estimated 336,068 tCO2e (metric tonnes of CO2e) in 2015.

### Light-duty vehicles

Within the two light-duty vehicles categories (cars and light trucks/vans), 2015 fuel type distributions (i.e., percent conventional vs. hybrid vs. electric cars, etc.) were estimated using national data on the U.S. car and light truck fleets.50 The top 99.9% of fuel types for both cars and light trucks were included for emissions calculation. All cars were assumed to be "short wheel base", and all long wheel base vehicles were assumed to be light trucks.

***Cars***

Due to insufficient data, the following technology types (indicated by gray shading in Table T2): flex-fuel, natural gas bi-fuel, natural gas, propane bi-fuel, propane, hydrogen fuel cells, electric-diesel hybrid, gasoline fuel cell, and methanol fuel cell (despite their small national presence) were counted as conventional internal combustion engine gasoline automobiles.

The rest, denoted by and orange double line, were explicitly included as fuel types in the calculations and were put in the following aggregate categories (Table T3):

- The Electric-Gasoline Hybrid technology type is found in the calculations as HEV (hybrid electric vehicle).
- Due to lack of data differentiating 100-Mile and 200-Mile Electric vehicles' efficiency (or relevant prevalence in New Haven), the two were combined for EV (electric vehicle).
- Similarly, the Plug-in 10 Gasoline Hybrid and Plug-in 40 Gasoline Hybrid were combined into a PHEV (plug-in hybrid electric vehicle) category.
- Other categories were renamed for simplicity: TDI Diesel ICE becomes "Diesel car" and Gasoline ICE Vehicles (plus the categories added) become "Car".

Once aggregate types of car categories were determined, their miles were apportioned to different fuels (Table T4). In Table T4, "Tech-fuel % of car miles" reflects the specific tech-fuel combination's estimated percent of New Haven car VMT. Below, methods for breaking down car technology miles further by fuel technology are detailed. These corrected percentages of total car VMT were then multiplied by 80.73% - the percent New Haven VMT produced by automobiles – to calculate each technology type's share of New Haven's total VMT (Table T4).

[50] (Appendix C p.29) "40. Light-Duty Vehicle Stock by Technology Type". Downloaded from the U.S. Energy Information Association: https://www.eia.gov/opendata/qb.php?category=2118520. *2017 Annual Energy Outlook Report, Table 40*. See: "Light-duty Vehicle Stock by Technology Type" Excel doc for data.

***Table T2. Initial technology types incorporated in analysis***

| Technology Type | Number (millions) | Percent total |
|---|---|---|
| Gasoline ICE Vehicles | 112.54 | 93.17% |
| Ethanol-Flex Fuel ICE | 3.52 | 2.91% |
| Electric-Gasoline Hybrid | 3.17 | 2.62% |
| TDI Diesel ICE | 0.93 | 0.77% |
| 100 Mile Electric Vehicle | 0.19 | 0.16% |
| Plug-in 10 Gasoline Hybrid | 0.12 | 0.10% |
| Plug-in 40 Gasoline Hybrid | 0.10 | 0.09% |
| 200 Mile Electric Vehicle | 0.09 | 0.07% |
| Natural Gas Bi-fuel | 0.06 | 0.05% |
| Natural Gas ICE | 0.05 | 0.04% |
| Propane Bi-fuel | 0.01 | 0.01% |
| Propane ICE | 0.00 | 0.00% |
| Fuel Cell Hydrogen | 0.00 | 0.00% |
| Electric-Diesel Hybrid | 0.00 | 0.00% |
| Fuel Cell Gasoline | 0.00 | 0.00% |
| Fuel Cell Methanol | 0.00 | 0.00% |
| **Total Car Stock** | **120.79** | **100.00%** |

(format for: combined with Gasoline ICE Vehicles)

Format for: technologies included in calculations

*Adapted from the 2017 Annual Energy Outlook Report, Table 40*[51]

***Table T3. Aggregate car types***

| Aggregate types | % of car miles |
|---|---|
| Car | 96.20% |
| HEV | 2.62% |
| Diesel car | 0.77% |
| EV | 0.23% |
| PHEV | 0.19% |
| **TOTAL** | 100.0% |

***Table T4. Car technology-fuel categories & calculated percentage of New Haven VMT***

| Tech-fuel categories | Tech-fuel % of car miles | % of 2015 NH VMT |
|---|---|---|
| Car: gasoline | 86.57% | 69.883% |
| Car: ethanol | 9.62% | 7.765% |
| HEV: gasoline | 2.36% | 1.906% |
| HEV: ethanol | 0.26% | 0.212% |
| Diesel car | 0.77% | 0.621% |
| EV | 0.23% | 0.186% |
| PHEV: electric | 0.10% | 0.084% |
| PHEV: gasoline | 0.08% | 0.062% |
| PHEV: ethanol | 0.01% | 0.007% |
| | **100.00%** | **80.73%** |

The car tech-fuel categories were calculated as follows:

- Car: gasoline and car: ethanol: in Connecticut, gasoline fuel at the pump is 10% ethanol and 90% unleaded gasoline. Thus, 10% of conventional gasoline automobile miles were reported as ethanol miles. The average age of all light-duty vehicles in 2014 was 11.4 years[52]. Thus as fine-scale age distribution data was not available, 2003 emission factors were used for all light-duty vehicles unless otherwise noted. Average mileage of automobiles was estimated as 23.2 mpg by the Bureau of Transportation Statistics[53].
- Hybrid electric vehicles (HEV): From the Alternative Fuels Data Center's "Hybrid and Plug-In Electric Vehicle Emissions Data Sources and Assumptions", average mileage for conventional HEV automobiles is

[51] "Table 40". United States Energy Information Association. *2017 Annual Energy Outlook Report.* See above.
[52] "Table 1-26: Average Age of Automobiles and Trucks in Operation in the United States". United States EPA. (Appendix C p.31).
[53] "Table 4-11: Light Duty Vehicle, Short Wheel Base and Motorcycle Fuel Consumption and Travel". U.S. Bureau of Transportation Statistics. (Appendix C p.32) https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_11.html

44.4 miles per gallon[54]. Battery energy costs are not included, as these are most relevantly tied to their source city's industrial emissions.

- Car: diesel: Due to lack of more specific data on diesel automobiles specifically, an average automobile mileage of 23.2 mpg was used for this category as well[55].
- All-electric vehicles (EV): Mileage per kilowatt-hour (kWh) was calculated by finding median mileage of all EVs listed on the fueleconomy.gov website from 1984-2015: 37 kWh per 100 miles[56]. The EPA eGRID emission factor for electricity use in NEWE region was used.[57]
- Plug-in hybrid electric vehicle (PHEV): Alternative Fuels Data Center's "Hybrid and Plug-In Electric Vehicle Emissions Data Sources and Assumptions" estimates that 55% of PHEV automobile miles are electric. From the same source, it is assumed that PHEV on gasoline have efficiency of 37.9 mpg and .367 kWh/mi.[58]
- Note on electric VMT: any electric cars charged within the city are likely to be included in Stationary Energy Scope 2 emissions (calculated elsewhere). Thus, to avoid some potential double-counting and due to lack of data on % electric VMT charged within New Haven, the following assumptions were made:
    - All highway/restricted access VMT are from charging stations outside of New Haven.
    - Half of unrestricted access VMT are from charging stations outside of New Haven. Emissions from electric VMT were adjusted:

*Table T5. Car VMT by road restriction level.*

| Access type | % Car VMT |
|---|---|
| Urban restricted access | 72.1 |
| Urban un-restricted access | 27.9 |

$$Thus, 100\% * 72.1\% + 50\% * 27.9\%$$
$$= 86.1\% \ of \ EV \ VMT \ emissions \ included \ in \ total.$$

***Pickup trucks/vans***

A breakdown of the United States' light truck on-road fleet was used to break down light truck miles by different fuel and technology types (Table T6)[59]. Due to a lack of data, the following alternate technologies were counted as conventional gasoline trucks: ethanol-flex fuel, natural gas bi-fuel, natural gas, propane, 100-mile and 200-mile electric, plug-in gasoline hybrids, and fuel cell hydrogen.[60] These categories are shaded gray in the table below and comprise 99.9% of United States light trucks.

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54 "Hybrid and Plug-in Electric Vehicle Emissions Data Sources and Assumptions". U.S. Department of Energy – Energy Efficiency and Renewable Energy *Alternative Fuels Data Center.* (Appendix C p.33) https://www.afdc.energy.gov/vehicles/electric_emissions_sources.html.

55 "Table 4-11: Light Duty Vehicle, Short Wheel Base and Motorcycle Fuel Consumption and Travel". Appendix C p. 32

56 Electric vehicles 1984-2015 fueleconomy.gov

57 https://www.epa.gov/energy/emissions-generation-resource-integrated-database-

58 "Hybrid and Plug-in Electric Vehicle". U.S. Dept. of Energy. See above. (Appendix C p.33)

59 "Table 40". United States Energy Information Association. *2017 Annual Energy Outlook Report.* See above.

60 Ethanol-Flex Fuel ICE Light Trucks were counted as conventional Gasoline ICE vehicles because little local data exists on the diverse flex fuel mixes' distribution of uses.

Similar to the automobile calculations, aggregate types were formed (Table T7): Gasoline ICE Vehicles plus all aforementioned categories become "Light truck: conventional", or "LT conventional" in the table below. Electric-Gasoline Hybrid becomes "LT HEV" (hybrid electric vehicle), TDI Diesel ICE becomes "LT diesel", and Propane Bi-fuel becomes "LT propane bi-fuel". Further apportionment into technology-fuel categories is detailed below

*Table T6. Initial light truck technology types incorporated in analysis*

*Adapted from the 2017 Annual Energy Outlook Report, Table 40*[61]

| Technology Type | Number (millions) | Percent total |
|---|---|---|
| Gasoline ICE Vehicles | 103.26 | 86.71% |
| Ethanol-Flex Fuel ICE | 14.84 | 12.46% |
| Electric-Gasoline Hybrid | 0.43 | 0.36% |
| TDI Diesel ICE | 0.33 | 0.28% |
| Propane Bi-fuel | 0.10 | 0.08% |
| Natural Gas Bi-fuel | 0.04 | 0.04% |
| Natural Gas ICE | 0.03 | 0.03% |
| Propane ICE | 0.02 | 0.02% |
| 100 Mile Electric Vehicle | 0.01 | 0.01% |
| Plug-in 10 Gasoline Hybrid | 0.01 | 0.01% |
| Plug-in 40 Gasoline Hybrid | 0.01 | 0.01% |
| 200 Mile Electric Vehicle | 0.00 | 0.00% |
| Fuel Cell Hydrogen | 0.00 | 0.00% |
| Electric-Diesel Hybrid | 0.00 | 0.00% |
| Fuel Cell Gasoline | 0.00 | 0.00% |
| Fuel Cell Methanol | 0.00 | 0.00% |
| **Total Light Truck Stock** | **119.09** | **100.00%** |

(format for: combined with Gasoline ICE Vehicles)

Format for: technologies included in calculations

*Table T7. Aggregate light truck type*

| Aggregate types | % of car miles |
|---|---|
| LT conventional | 99.28% |
| LT HEV | 0.36% |
| LT diesel | 0.28% |
| LT propane bi-fuel | 0.08% |
| **TOTAL** | **100.00%** |

*Light truck = "LT"*

*Table T8. LT technology-fuel categories & calculated percentage of New Haven VMT*

| Tech-fuel categories | Tech-fuel % of car miles | % of 2015 NH VMT |
|---|---|---|
| LT conventional: gas | 89.36% | 11.336% |
| LT conventional: ethanol | 9.93% | 1.260% |
| LT HEV: gas | 0.32% | 0.041% |
| LT HEV: ethanol | 0.04% | 0.005% |
| LT diesel | 0.28% | 0.035% |
| LT propane bi-fuel propane | 0.04% | 0.5% |
| LT propane bi-fuel gas | 0.04% | 0.5% |
| **TOTAL** | **100.00%** | **12.686%** |

[61]"Table 40". United States Energy Information Association. *2017 Annual Energy Outlook Report*. See above.

The technology-fuel categories were calculated as follows:

- Light truck: conventional: gasoline light-duty truck mileage from 2013 data provided by the Alternative Fuels Data Center: 17.2 mpg.[62] Mileage on ethanol was assumed to be the same.
- Light truck: HEV: median (combined city/highway) mileage of all listed HEV 1994-2015 hatchbacks, station wagons, pickup trucks, SUVs, minivans and vans on the fueleconomy.gov website (US EPA) was 26 mpg.[63]
- Light truck: diesel: diesel truck mileage from 2013 data provided by the Alternative Fuels Data Center: 19 mpg.[64]
- Light truck: Propane bi-fuel: fuel economies estimated by taking median mpg of 1994-2015 propane bi-fuel light-duty trucks on fueleconomy.gov[65]: 15 mpg on gasoline and 11 mpg on liquid propane gas. Median year was 2003; hence, 2003 gasoline light truck emission factors were used. Half of propane bi-fuel truck miles were allocated to each fuel type, as a broad search of this vehicle type appeared to yield a similar ratio.

### *Motorcycles*

Fuel economy: 2014 estimate from the US EPA: 43.6 mpg[66]. All assumed to run on 100% gasoline.

### *Buses*

All buses were assumed to run on diesel, as more detailed data on distribution of all bus types' fuel technologies was not available. Fuel economy: 2014 data from by the US EPA: 7.2 mpg[67].

### *Single-unit heavy-duty vehicles*

All assumed to run on diesel. Fuel economy from US EPA[68]: 7.3 mpg.

### *Combination trucks*

All assumed to run on diesel. 2013 mileage data from US EPA. [69]: 5.8 mpg.

All emission factors and percentages of New Haven YVMT by vehicle technology-fuel combination were combined in one table (below). Then, total New Haven on-road emissions of $CO_2$, $CH_4$, and $N_2O$ were calculated per one VMT. For example:

$$\text{Car: gasoline } CO_2 \text{ emissions} = \frac{1 \text{ mile} * 69.9\%}{23.2 \frac{\text{miles}}{\text{gallon}}} * 8.78 \frac{\text{kg } CO_2}{\text{gal}} = 0.26 \text{ kg } CO_2$$

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[62]"Average Fuel Economy of Major Vehicle Categories". Alternative Fuels Data Center. (Appendix C p.35) https://www.afdc.energy.gov/data/.
[63] See: "truck HEV mileages" Excel document.
[64]"Average Fuel Economy of Major Vehicle Categories". See above.
[65] Fueleconomy.gov propane bi-fuel trucks
[66] "Table 4-11: Light Duty Vehicle, Short Wheel Base and Motorcycle Fuel Consumption and Travel". See above.
[67] "Table 4-15: Bus Fuel Consumption and Travel". U.S. Bureau of Transportation Statistics. (Appendix C p.36)
[68] "Table 4-13: Single-Unit 2-Axle 6-Tire or More Truck Fuel Consumption and Travel". U.S. Bureau of Transportation Statistics. (Appendix C p.37)
[69] "Table 4-14: Combination Truck Fuel Consumption and Travel". U.S. Bureau of Transportation Statistics. (Appendix C p.38)

$$\text{Car: gasoline } CH_4 \text{ emissions} = 1 \text{ mile} * 69.9\% * \frac{0.0114 \text{ g } CH_4}{\text{mile}} * \frac{1\text{kg}}{1000\text{g}} = 7.97 * 10^{-6} \text{ kg } CH_4$$

Then, the total per-mile emissions of each gas were entered in the GPC Reporting Tool as an emission factor. Since New Haven's 2015 YVMT was estimated at 733,750,740 miles, the tool converted these miles using the emission factor to an estimated 336,068 $tCO_2e$ emitted in 2015 by on-road transportation.

*Table T9. Calculation of New Haven on-road vehicle emissions per one vehicle mile traveled*

| | | | | | | | Emissions (kg) *(calculated)* | | |
|---|---|---|---|---|---|---|---|---|---|
| **Technology-fuel combination** | **% VMT** | **kWh/mi** | **mpg** | **kg $CO_2$/gal** | **g $CH_4$/mi** | **g $N_2O$/mi** | **$CO_2$** | **$CH_4$** | **$N_2O$** |
| Car: gasoline | 69.883% | | 23.2 | 8.78 | 0.0114 | 0.0135 | 0.264473 | 7.97E-06 | 9.43E-06 |
| Car: ethanol | 7.765% | | 23.2 | 5.75 | 0.055 | 0.067 | 0.019245 | 4.27E-06 | 5.20E-06 |
| Diesel car | 0.621% | | 23.2 | 10.21 | 0.0005 | 0.001 | 0.002735 | 3.11E-09 | 6.21E-09 |
| EV (electricity) | 0.186% | 0.37** | | | | | 0.000153 | 2.57E-08 | 3.44E-09 |
| Car HEV gasoline | 1.906% | | 44.4 | 8.78 | 0.0173 | 0.0036 | 0.003769 | 3.30E-07 | 6.86E-08 |
| Car HEV ethanol | 0.212% | | 44.4 | 5.75 | 0.055 | 0.067 | 0.000274 | 1.16E-07 | 1.42E-07 |
| Car PHEV electric | 0.084% | 0.367** | | | | | 0.000069 | 1.16E-08 | 1.55E-09 |
| Car PHEV gasoline | 0.062% | | 37.9 | 8.78 | 0.0173 | 0.0036 | 0.000144 | 1.07E-08 | 2.23E-09 |
| Car PHEV ethanol | 0.007% | | 37.9 | 5.75 | 0.055 | 0.067 | 0.000010 | 3.79E-09 | 4.62E-09 |
| LT conv.: gasoline | 11.336% | | 17.2 | 8.78 | 0.0155 | 0.0114 | 0.057865 | 1.76E-06 | 1.29E-06 |
| LT conv.: ethanol | 1.260% | | 17.2 | 5.75 | 0.055 | 0.067 | 0.004211 | 6.93E-07 | 8.44E-07 |
| LT HEV: gasoline | 0.041% | | 26 | 8.78 | 0.0163 | 0.0066 | 0.000138 | 6.66E-09 | 2.70E-09 |
| LT HEV: ethanol | 0.005% | | 26 | 5.75 | 0.055 | 0.067 | 0.000010 | 2.50E-09 | 3.04E-09 |
| LT diesel | 0.035% | | 19 | 10.21 | 0.001 | 0.0015 | 0.000189 | 3.52E-10 | 5.28E-10 |
| LT propane bi-fuel gas | 0.005% | | 13.5 | 8.78 | 0.0155 | 0.0114 | 0.000033 | 7.86E-10 | 5.78E-10 |
| LT propane bi-fuel propane | 0.005% | | 11 | 5.72 | 0.037 | 0.067 | 0.000026 | 1.88E-09 | 3.40E-09 |
| motorcycle gasoline | 0.488% | | 43.5 | 8.78 | 0.0672 | 0.0069 | 0.000984 | 3.28E-07 | 3.37E-08 |
| bus diesel | 0.145% | | 7.2 | 10.21 | 0.0051 | 0.0048 | 0.002055 | 7.39E-09 | 6.96E-09 |
| heavy-duty: single unit | 2.277% | | 7.3 | 10.21 | 0.0051 | 0.0048 | 0.031851 | 1.16E-07 | 1.09E-07 |
| heavy-duty: combination | 3.678% | | 5.8 | 10.21 | 0.0051 | 0.0048 | 0.064741 | 1.86E-07 | 1.77E-07 |
| **Per one vehicle mile traveled:** | **100.000%** | | | **Per one vehicle mile traveled:** | | | **0.452976** | **0.000016** | **0.000017** |

*Note: electricity usage calculation included the following (approximate) factors which were excluded from this table for brevity:* 0.26 kg $CO_2$/kWh, 4.35E-05 kg $CH_4$/kWh, and 5.82E-06 kg $N_2O$/kWh. *All electricity emissions were multiplied by 86.1% to allow for out-of-town charging.*

*Table T10. On-road transportation EPA Emission Factors: years and categories used*

| Vehicle/fuel | Gas | Table | Category | Year |
|---|---|---|---|---|
| All/gasoline | $CO_2$ | 2 | Motor gasoline | |
| All/ethanol | $CO_2$ | 2 | Ethanol (100%) | |
| Light-duty vehicle/ethanol | $CH_4$, $N_2O$ | 4 | Ethanol Light-duty Vehicles | |
| All/diesel | $CO_2$ | 2 | Diesel Fuel | |
| Conventional car/gasoline | $CH_4$, $N_2O$ | 3 | Gasoline Passenger Cars | 2003 |
| HEV car/gasoline | $CH_4$, $N_2O$ | 3 | Gasoline Passenger Cars | 2009-present |
| Diesel car/diesel | $CH_4$, $N_2O$ | 4 | Diesel Passenger Cars | 1996-present |
| PHEV car/gasoline | $CH_4$, $N_2O$ | 3 | Gasoline Passenger Cars | 2009-present |
| Conventional light truck/gasoline | $CH_4$, $N_2O$ | 3 | Gasoline Light-duty Trucks | 2003 |
| HEV truck/gasoline | $CH_4$, $N_2O$ | 3 | Gasoline Light-duty Trucks | 2008-present |
| Diesel light truck/diesel | $CH_4$, $N_2O$ | 4 | Diesel Light-duty Trucks | 1996-present |
| Propane bi-fuel truck/gasoline | $CH_4$, $N_2O$ | 3 | Gasoline Light-duty Trucks | 2003 |
| Propane bi-fuel truck/propane | $CO_2$ | 2 | Liquefied Petroleum Gases (LPG) | |
| | $CH_4$, $N_2O$ | 4 | LPG Light-duty vehicles | |
| Motorcycle/gasoline | $CH_4$, $N_2O$ | 4 | Gasoline Motorcycles | 1996-present |
| Bus/diesel | $CH_4$, $N_2O$ | 4 | Diesel Medium-and Heavy-duty Vehicles | |
| Single-unit heavy-duty/diesel | $CH_4$, $N_2O$ | 4 | Diesel Medium-and Heavy-duty Vehicles | |
| Combination heavy duty/diesel | $CH_4$, $N_2O$ | 4 | Diesel Medium-and Heavy-duty Vehicles | |

*Source:* Emission Factors for Greenhouse Gas Inventories. U.S. Environmental Protection Agency. Web: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

## II.2 Railways

### II.2.1 Emissions from fuel combustion for railway transportation occurring in the city

*Shoreline East diesel locomotives*

As Shoreline East (SLE) did not respond to multiple requests for information, 2002 estimated diesel fuel consumption reported in the New Haven Air Toxics inventory[70] was prorated to 2017[71] activity levels. In 2002, the inventory reported the following method of diesel consumption estimation:

- SLE ran eight diesel locomotives per day overall consuming 14,000 gallons diesel weekly.
- SLE's engineer estimated that trains were in New Haven for 18 out of every 24 hours.

Thus, 2002 diesel consumption = 14,000*(52)*(18/24) = 546,000 gallons per year.

In 2017 (and to the best of our knowledge, searching the history of SLE's fleet, in 2015), SLE ran 17 locomotives per day:

$$546{,}000\ gallons\ per\ year\ in\ 2002\ * \frac{17\ trains\ in\ 2015}{8\ trains\ in\ 2002} = 1{,}160{,}250\ gallons\ per\ year\ in\ 2015.$$

This fuel consumption was converted within the GPC Reporting Tool using the "Diesel Fuel" and "Diesel Locomotive" EPA Emissions Factors. Shoreline East's train activity in 2015 thus emitted an estimated 11,952 $tCO_2e$.

*This estimate required the assumption that activity patterns and locomotive consumption efficiency was the same across the two years, which probably is not accurate. Thus, it is recommended that efforts be renewed to obtain new data from SLE.

*Amtrak diesel locomotives*

Laura Fotiou and Rachel Cohen at Amtrak Environment and Sustainability[72][73] provided diesel fuel consumption by Amtrak trains based on train miles and frequency traveled in New Haven. They used The Climate Registry's Emission Factors for 2016. Emissions were provided in $CO_2e$ and broken down by gas:

*Table T11. Amtrak Scope 1 Emissions: diesel locomotives*

| Gas | Metric tons $CO_2e$ |
|---|---:|
| $CO_2$ | 137.62 |
| $CH_4$ | 0.30 |
| $N_2O$ | 0.93 |
| **TOTAL $CO_2e$** | **138.85** |

[70] "New Haven Air Toxics Inventory and Risk Reduction Strategy." Madeleine R. Weil, New Haven Community Clean Air Initiative (2004).

[71] As no archive of former train schedules was found, the April 2017 schedule was downloaded from the Shoreline East website.

[72] Laura.Fotiou@amtrak.com, Rachel.Cohen@amtrak.com

[73] Correspondence with Amtrak – Cohen, Rachel M and Fotiou, Laura. (Appendix C p.39)

These $CO_2e$ values were recorded as-is in the GPC Reporting Tool.

The total of SLE and Amtrak diesel locomotives' emissions in 2015 is thus estimated to be 12,091 $tCO_2e$.

### II.2.2 Emissions from grid-supplied energy consumed in the city for railways

#### *Metro-North locomotives*

The Metro North New Haven line is entirely electrified. According to Ted Novicki at United Illuminating, Metro-North's electricity is supplied by United Illuminating. Thus, emissions from rail electricity consumption by Metro-North trains are most likely included in Stationary Scope 2 emissions calculations.

## II.3 Waterborne Navigation

### II.3.1 Emissions from fuel combustion for waterborne navigation occurring in the city

#### *Marine diesel fuel*

Little data on within-boundary marine vessel diesel consumption were available, so 2014 New Haven consumption was estimated based off New York City Greenhouse Gas Inventory[74] numbers[75]. Total shipping weight in 2015 for each city's port was used to approximate port activity and thus relative differences in marine vessel diesel consumed by local operation boats (below table).[76]

*Table T12. 2015 Shipping Weights[i] by City Ports*

| | EXPORTS | IMPORTS | Total |
|---|---|---|---|
| **New Haven** | 115.7 | 2,541.9 | **2657.6** |
| **New York City** | 15,791.6 | 59,276.5 | **75068.1** |

*i.Weight units not declared in source.*

New York City estimated that in 2014, their local operation boats consumed 18,418,732 liters of marine vessel diesel:

$$18{,}418{,}732\ liters\ (NYC) * \frac{2{,}657.6}{75{,}068.1} = 652{,}069.66\ liters\ (New\ Haven)$$

This consumption estimate was converted within the GPC Reporting Tool using the "Diesel Ships and Boats" EPA Emissions Factor (units converted from gallons to liters). The resulting 2015 diesel fuel emissions from marine activity in New Haven is estimated at 10,358 $tCO_2e$.

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74 New York City also followed the GPC protocol, assuring that the same criteria for Scope I fuel consumption were used.

75 http://www.nyc.gov/html/dem/downloads/pdf/NYC_GHG_Inventory_2014_Released_2016.pdf

76 https://www.census.gov/foreign-trade/Press-Release/2015pr/12/ft920/ft920.pdf

## II.4 Aviation

Due to lack of data on Scope 1 aviation emissions (which per GPC only includes local flights – those both taking off and landing in the city, and for the most part taking place within city boundaries), the 2015 inventory does not include any number estimating emissions from aviation.

# III – Waste

## Quantifying New Haven waste tonnages and destinations

### *Municipal Solid Waste (MSW)*

The latest data available on New Haven's MSW production and destination of MSW are from 2013: in that year, New Haven produced 103,991 tons of MSW.[77][78] New Haven's population in 2013 was slightly smaller than in 2015, so the following adjustment was made to estimate 2015 waste tonnage:[79,80]

$$103{,}991 * \frac{130{,}612}{130{,}338} = 104{,}209 \text{ tons waste estimated for 2015}$$

Table W1 presents a simplified version of 2013 New Haven MSW production, destination Resource Recovery Facility (RRF, the first stop of MSW after leaving New Haven) and 2015 production estimate.

*Table W1. New Haven MSW production estimate in 2015*

| **RRF** | **2013 received from New Haven (tons)** | **2015 est. from New Haven (tons)** *(calculated)* |
|---|---|---|
| **Bridgeport** | 48,958.3 | 49,061.3 |
| **Bristol** | 5,029.8 | 5,040.4 |
| **Lisbon** | 11,462.4 | 11,486.5 |
| **Mid-CT** | 37,472.4 | 37,551.1 |
| **Wallingford** | 203.1 | 203.5 |
| **Stratford (transfer station)** | 789.2 | 790.8 |
| **Winters Bros (transfer station)** | 75.4 | 75.6 |
| **TOTAL** | **103,990.5** | **104,209.1** |

The next step was to calculate tonnages of MSW burned, recycled and landfilled.

[77] "New Haven MSW Reported Received for Disposal by CT Solid Waste Facilities FY2013" (Appendix D p.41). Judy Belaval, CT Department of Energy and Environmental Protection (DEEP).
**Note**: through correspondence with Resource Recovery Facilities staff we know that the destination of New Haven MSW has changed drastically over the past several years. While the 2013 data may not reflect precisely the conditions in 2015, by the next GHG Inventory update, CT DEEP will hopefully be able to provide data which reflect those changes.
[78] In the entirety of the Waste section, waste is measured in short tons (U.S. tons) and emissions in $CO_2e$ are reported in metric tonnes – tCO2e.
[79] 2009-2013 American Community Survey 5-Year Estimates: United States Census Bureau American FactFinder. https://factfinder.census.gov/
[80] "Selected Housing Characteristics – 2011-2015 American Community Survey 5-Year Estimates". U.S. Census Bureau. *American Fact Finder.*

Percentage 2013 MSW burned was given in the data on New Haven 2013 MSW production. In addition, quantities diverted within the Resource Recovery Facility (RRF) – assumed recycled – and quantity metal recycled pre-combustion were provided. Percentage of the total waste received by the RRFs that was directed to landfill was calculated thus: [81]

$$2013\ Proportion\ waste\ landfilled = \frac{(2013\ Waste\ not\ burned) - (2013\ Waste\ to\ RRF\ precombustion) - (2013\ Metal\ recycled\ precombustion)}{2013\ Total\ waste}$$

Then, this total percentage landfilled in 2013 was applied to New Haven's 2015 estimated waste production, producing estimates for New Haven MSW landfilled in 2015: 2,907 tons (Table W2).

Percent MSW incinerated in 2013 was given in the 2013 data on New Haven waste production and applied to estimated 2015 New Haven MSW production to estimate quantity MSW incinerated in 2015 (Table W2). Resource Recovery Facilities (RRFs, where waste is burned to produce electricity) were surveyed to find out incinerator type. RRFs fed by transfer stations and the former Wallingford and Mid-CT RRFs – where survey was not possible – were assumed to be semi-continuous stoker technology (since semi-continuous is higher emitting, this can be considered a conservative assumption). Metal was recycled pre-combustion in the waste stream destined for semi-continuous stoker incineration, so the waste fraction percentages originally provided by CT DEEP were adjusted accordingly.[82]

*Table W2. Destinations and quantities of New Haven MSW*

| RRF | NH 2015 MSW (tons) *(calculated)* | % Waste Burned | NH MSW burned (tons) *(calculated)* | Destination | % landfilled 2013 *(calculated)*[a] |
|---|---|---|---|---|---|
| Bridgeport | 49,061.3 | 100.0% | 49,061.3 | Cont. stoker | 0.0% |
| Bristol | 5,040.4 | 98.5% | 4,964.3 | Cont. stoker | 0.2% |
| Lisbon | 11,486.5 | 100.0% | 11,486.5 | Semi-cont. stoker | 0.0% |
| Mid-CT | 37,551.1 | 92.1% | 34,595.9 | Semi-cont. stoker | 6.1% |
| Wallingford | 203.5 | 95.4% | 194.2 | Semi-cont. stoker | 4.1% |
| Stratford (TS) | 790.8 | 40.2% | 318.2 | Semi-cont. stoker | 59.8% |
| Winters Bros (TS) | 75.6 | 97.4% | 73.6 | Semi-cont. stoker | 2.6% |
| **TOTAL** | 104209.1 | | **100482.6** | | **2,907 tons to landfill: 2.790%** |

*Amount New Haven MSW incinerated by incineration technology, and amount New Haven MSW sent to landfill.*

a) *See "% landfill" tab of "*MSW destination calculations*" for source of this value.*

[81] See Appendix D p.41-45 for calculation of MSW destination and metal recycling.
Excel document: "MSW destination calculations"

[82] See the set of MSW destination calculation sheets defined above.

*Construction and Demolition Waste (C&D)*

The source serving as a basis for calculating New Haven C&D waste emissions is the "Construction and Demolition Waste Characterization and Market Analysis"[83]. The report provides a .29 ton per-capita waste production of CT citizens, and accounting for the 7% C&D recycling rate given in the report, this per-capita rate applied to the 2015 New Haven population yields an estimated yearly C&D waste production of 35,226 tons.[84] (New Haven population is estimated at 130,612.)[85]

Though the report broke down destination of waste disposed in-state, out-of-state disposal (82% of total) was not specified and thus assumed to be landfill (the report does mention that more than half went to a single Ohio landfill) – thus 28,885 tons were assumed landfilled out-of-state. In-state, New Haven waste (18% of total) was either incinerated (59.8% of in-state) or disposed of (assumed landfill). Thus, 18% * 59.8% * 35,226 tons yields 3,792 tons incinerated in-state. Similarly, we find that 18% * 40.2% * 35,226 tons yields 2,549 tons landfilled in-state.

Combining the percentages landfilled of waste processed in-state and waste processed out-of-state yields 31,434 tons C&D waste landfilled and 3,792 tons incinerated in 2015 (Table W3).

*Table W3. Total amounts of C&D waste by destination and disposal method.*

| Destination | Landfilled (short tons) | Incinerated (short tons) | Total |
|---|---|---|---|
| In-state | 2,549 | 3,792 | 6,341 |
| Out-of-state *( disposal method assumed)* | 28,885 | 0 | 28,885 |
| **TOTAL** | **31,434** | **3,792** | **35,226** |

## III.1 Solid waste disposal

### III.1.2 Emissions from solid waste generated in the city but disposed in landfills or open dumps outside the city

All landfilled New Haven solid waste was disposed in landfills outside the city (Scope 3 – GPC III.1.2).

[83] "Construction and Demolition Waste Characterization and Market Analysis". Prepared for CT DEEP by Green Seal Environmental, Inc in partnership with Sovereign Consulting Inc.
PDF file: "CMMS_Final_2016_Construction_&_Demolition_Waste_Characterization"
[84] For calculation of C&D waste destination breakdown, see Appendix D. p.46
Excel document: "Construction and Demolition Waste calculation"
[85] 2011-2015 U.S. Census American Community Survey 5-year estimates. See above.

### *Municipal Solid Waste (MSW)*

Waste composition of New Haven MSW was estimated using a CT-wide 2015 study of MSW.[86] The GPC methane commitment model (along with GPC default factors[87]) (Figure 1) was utilized to estimate GHG emissions of New Haven MSW landfilled. This method was deemed most suitable because it represents the potential impact of waste production from the inventory year. With this method, an emission factor per short ton of MSW was obtained and converted to total CO2e in the GPC reporting tool: landfilled MSW from New Haven in 2015 produced an estimated emissions of 3,102 tCO2e.

**Equation 8.3 Methane commitment estimate for solid waste sent to landfill**

$$CH_4 \text{ emissions} = MSW_x \times L_0 \times (1\text{-}f_{rec}) \times (1\text{-}OX)$$

| Description | | | Value |
|---|---|---|---|
| $CH_4$ emissions | = | Total $CH_4$ emissions in metric tonnes | Computed |
| $MSW_x$ | = | Mass of solid waste sent to landfill in inventory year, measured in metric tonnes | User input |
| $L_0$ | = | Methane generation potential | Equation 8.4 Methane generation potential |
| $f_{rec}$ | = | Fraction of methane recovered at the landfill (flared or energy recovery) | User input |
| OX | = | Oxidation factor | 0.1 for well-managed landfills; 0 for unmanaged landfills |

*Source:* Adapted from *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*

*Figure 9.* The methane commitment model, as illustrated by *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*

### *Construction and Demolition (C&D) Waste*

The source serving as a basis for calculating New Haven C&D waste emissions is the "Construction and Demolition Waste Characterization and Market Analysis"[88]. Utilizing this waste characterization data, the methane commitment for the estimated 31,434 tons waste landfilled was calculated as per GPC guidelines[89]. A $CH_4$ emission factor per ton of waste then was converted to $CO_2e$ within the GPC reporting tool. Overall, New Haven C&D waste estimated produced in 2015 will emit 46,679 tCO2e.

[86] "2015 Statewide Waste Characterization Study". Prepared for CT DEEP by MSW Consultants, Cascadia Consulting Group and DSM Environmental Services, Inc.
"CMMS_Final_2015_MSW_Characterization_Study" pdf.
[87] Appendix D p.47 for calculations and factors used.
"MSW landfill emissions calculation" Excel document.
[88]"Construction and Demolition Waste Characterization and Market Analysis". See above.
[89] Appendix D p.48. Excel file: "Construction and Demolition waste calculation".

## III.3 Incineration and open burning

### III.3.2 Emissions solid waste generated within but treated [burned] outside of the city (Scope 3)

All New Haven solid waste burned was burned outside of the city boundary; thus, we deal only with Scope 3 emissions (GPC III.3.2).

*Municipal Solid Waste (MSW)*
GPC protocol was followed for calculating a four-gas ($CO_2$, biogenic $CO_2$, $CH_4$, and $N_2O$) emission factor for incinerated waste; separate emission factors were calculated for each of the two incineration technologies. [90,91] The calculated emission factors per short ton of waste for all four gases and two incineration technologies were entered in the GPC reporting tool. Overall, New Haven MSW incinerated in 2015 is estimated to have emitted 36,501 tCO2e, and in addition 66,259 tonnes of biogenic $CO_2$, coming from incinerated organics.

*Construction and Demolition (C&D) Waste*
The source serving as a basis for calculating New Haven C&D waste emissions is the "Construction and Demolition Waste Characterization and Market Analysis"[92]. Utilizing this waste characterization data and following the same GPC protocol as for MSW, emission factors per short ton of C&D waste for $CO_2$ (non-biogenic and biogenic), $CH_4$, and $N_2O$ were calculated and input to the GPC reporting tool for an automatic calculation of total emission per year. The 3,792 tons New Haven C&D waste incinerated produced 462 tCO2e plus an additional 2,733 $tCO_2$ from organic materials.[93]

*Table W4. Summary of New Haven waste emissions by disposal method*

| Disposal Method | Incineration emissions ($tCO_2e$)* | Landfill emissions ($tCO_2e$)** | Total emissions ($tCO_2e$) |
|---|---|---|---|
| Municipal Solid Waste | 100,934 | 3,102 | 104,036 |
| C&D Waste | 3,196 | 46,679 | 49,875 |

**Includes biogenic emissions.* *** Emissions are methane "commitment" or expected future emissions*

[90] (Appendix D p. 49-53)
"Incineration emissions calculation final" Excel document.
[91] See the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*, p 96-99 for equations.
Calculation factors were obtained from Table 2.4 and Table 2.5 from "Chapter 2:Waste Generation, Composition and Management Data" by Pipatti, Sharma and Yamada et al., 2006, *2006 IPCC Guidelines for National Greenhouse Gas Inventories, 5*, p. 14. (Appendix D p.54)
[92]Prepared for CT DEEP by Green Seal Environmental, Inc in partnership with Sovereign Consulting Inc. See above.
[93] (Appendix D p. 55-57)

## III.4 Wastewater treatment and discharge

### III.4.1 Emissions from wastewater generated and treated within the city

Gary Zrelak at the Greater New Haven Water Pollution Control Authority provided their own inventory numbers for emissions from New Haven wastewater treatment. Overall, these processes emitted 5,795 $tCO_2e$ in 2015. A greenhouse gas breakdown between $CO_2$, $N_2O$, and $CH_4$ was provided for the portion of emissions corresponding to incineration only.[94]

[94] (Appendix D page 58: "Emissions from New Haven Wastewater Treatment") GZrelak@gnhwpca.com