CITY OF KEENE

2015 Greenhouse Gas Emissions Inventory

1995 Calendar Year Baseline

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CITY OF KEENE, NH
2015 GREENHOUSE GAS EMISSIONS INVENTORY

ACKNOWLEDGEMENTS

This document was prepared for the City of Keene by Southwest Region Planning Commission (SWRPC) with input from the City of Keene's Cities for Climate Protection (CCP) Committee. Initial data collection and preliminary data analysis were completed by Andrew Graham and Samantha Gaudette, former interns at the City of Keene Planning Department.

The following agencies provided data and support in ensuring the accuracy of the greenhouse gas report: ICLEI – Local Governments for Sustainability, Eversource, Keene Gas, Liberty Utilities, Home, Healthcare, Hospice and Community Services, and SWRPC. In addition, City of Keene staff from various departments provided the data and insight necessary to complete this report. The City and SWRPC are grateful for the contributions from these individuals, who are listed below.

The preparation of this document has been financed in part through grant(s) from the Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation, under the State Planning and Research Program, Section of Title 23, U.S. Code. The contents of this report do not necessarily reflect the official views or policy of the U.S. Department of Transportation.

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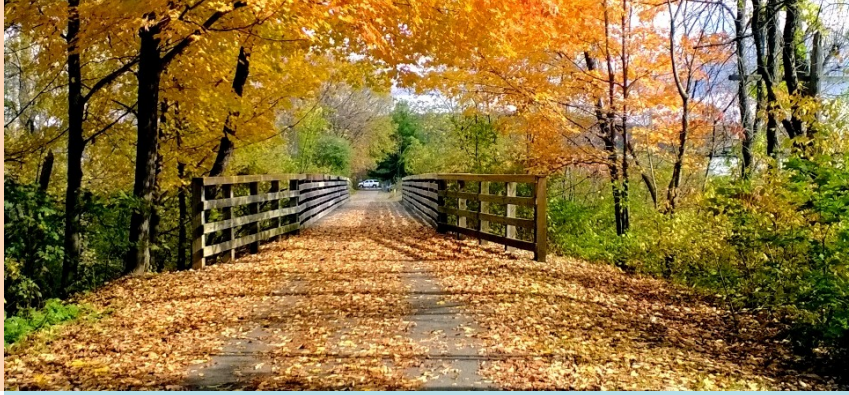


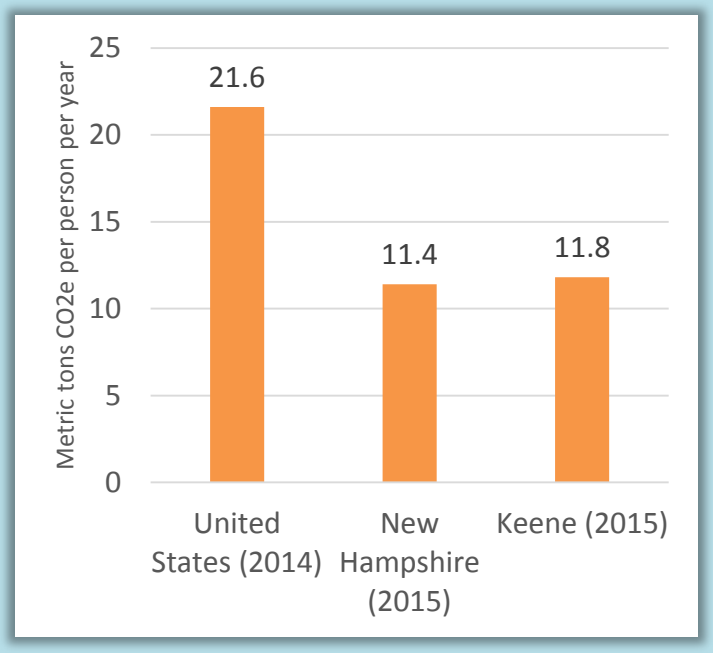
EXECUTIVE SUMMARY

In 2004, the City of Keene made a commitment to reduce its greenhouse gas (GHG) emissions. As part of this commitment to climate leadership, the City established two GHG emissions reduction targets, one for community-wide emissions and one for municipal operations. The first target calls for a 10% decrease in GHG emissions from the community below 1995 levels by 2015. The second target is more ambitious and calls for a 20% decrease in GHG emissions from municipal operations over the same timeframe. This report includes a 2015 GHG emissions inventory for both community-wide and municipal operations and compares each to the 1995 baseline GHG inventory.

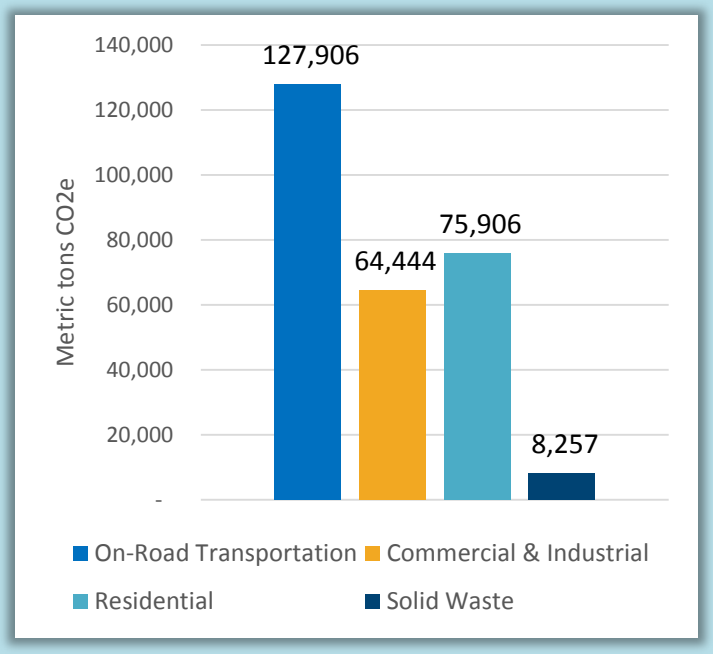
2015 Community Inventory Results

Community-wide emissions decreased from 284,511 tons carbon dioxide equivalents (CO2e) in 1995 to 276,512 tons CO2e in 2015, a 2.8% decrease in overall emissions and a 5.4% decrease in per capita emissions. The largest contributor to emissions is on-road transportation, followed by emissions from commercial and industrial energy use, residential energy use, and solid waste generated by the community.

Factors that contributed to emissions reductions include an increase in the overall fleet fuel economy, fewer heating degree days in 2015 compared to 1995, fuel switching from fuel oil to propane, a cleaner electricity supply, increases in energy efficiency among the Commercial and Industrial Sector, and a reduction in waste generation coupled with an increase in residential and commercial recycling and composting.



United States, New Hampshire, and Keene per capita emissions comparison in metric tons of CO2e per person per year. Sources: U.S. EPA (U.S. figure) and U.S. EIA. (NH figure).



Keene, NH community-wide emissions by sector in metric tons CO2e.

2015 Municipal Inventory Results

Municipal emissions decreased from 5,899 tons CO2e in 1995 to 4,423 tons CO2e in 2015, a 25% decrease in GHG emissions. The City of Keene has implemented a variety of energy efficiency and cost savings measures over the past 20 years that have led to significant emissions reductions for municipal operations, including the installation of a geothermal HVAC system at the Keene Public Works Department, the installation of hydroelectric turbines at the Water Treatment Plant, various building envelope and lighting upgrades, the installation of a solar PV system at Keene City Hall, and the use of biodiesel for the City vehicle fleet, among others.

Emissions from the Keene Municipal Landfill, which are included in Section 4 of this report, decreased from 205,064 tons CO2e in 1995 to 8,820 tons CO2e in 2015, a 96% decrease in emissions. This decrease in emissions is partially due to the decrease in organic material in the landfill available to undergo decay, and partially due to the installation of a landfill gas collection system at the landfill, which is estimated to have avoided about 830,760 tons CO2e in 1995 and 2015.

These results indicate that the City's efforts to reduce energy use and save costs have been an overwhelming success.

CITY OF KEENE
Greenhouse Gas Reduction Targets

1. **Reduce Community-wide emissions by 10%.** *Reduce emissions from the entire community to 10% below 1995 levels by 2015.*

2. **Reduce municipal emissions by 20%.** *Reduce emissions from the operation of Keene's local government to 20% below 1995 levels by 2015.*

Source: City of Keene Climate Action Plan, adopted by City Council on February 19, 2004

Keene, NH municipal emissions by sector in metric tons CO2e.

"Over the last decade, Keene has worked to address sustainability through measures to lower greenhouse gas emissions and increase community resiliency to the expected impacts of a changing climate. By addressing climate change through collaborative planning and action, the community can foster long-term environmental, social, and economic vitality within Keene and the Monadnock region."

- Keene Comprehensive Master Plan (2010)

1. INTRODUCTION

1.1 Background

The City of Keene understands that Climate Change poses a new and complex challenge for the City and surrounding region. In 2000, the City of Keene signed on to the Cities for Climate Protection Campaign, a program administered by Local Governments for Sustainability USA (ICLEI, formerly the International Council on Local Environmental Initiatives). By signing on to this campaign, the City made a commitment to develop and implement a climate action plan that sets clear targets for reducing greenhouse gas (GHG) emissions.

The effort to track Keene's GHG emissions began in 2000 when the City developed a baseline GHG inventory report using data from 1995. This report predicted that by 2015, without taking any action, the community's emissions would increase by 26%. In response, the Keene Cities for Climate Protection (CCP) committee led an effort to create a climate action plan that identifies measures the City and wider community can take to reduce GHG emissions. This plan, which was adopted by City Council in 2004, also established two GHG reduction targets, one for the community and one for municipal operations. The first target, which includes residential, commercial, transportation, and solid waste sectors, calls for a 10% decrease in GHG emissions from the community below 1995 levels by 2015. The second target is more ambitious and calls for a 20% reduction in GHG emissions from municipal operations below 1995 levels by 2015.

This report provides an updated community-wide inventory of 2015 GHG emissions as well as an updated inventory of 2015 GHG emissions from municipal operations, which is a subset of the community-wide inventory. This information will not only help the City monitor its performance against its goals but will also inform ongoing climate action planning.

1.2 Planning Process

The City and the CCP committee have utilized a system established by ICLEI to assist communicating the process necessary to achieve GHG reductions. They have also utilized this system to communicate the *progress* the City has made over the ten years toward their reductions of greenhouse gases:

- **Milestone 1:** Conduct a baseline emissions inventory and forecast.
- **Milestone 2:** Set an emissions reduction target.
- **Milestone 3:** Develop a local action plan for reducing emissions.
- **Milestone 4:** Implement policies and measures.
- **Milestone 5:** Monitor emissions reductions and verify results.

In particular, this report addresses Milestone 5: Monitor emissions reductions and verify results.

1.3 Methodology

This report includes two analyses: a 2015 Community Inventory and a 2015 Municipal Operations Inventory. The Community Inventory uses publicly available data to profile Keene's community-wide emissions. The Municipal Inventory, which is a subset of the Community Inventory, uses data from the operations of Keene's government to profile municipal operations in greater detail. In addition, this report compares the results of the 2015 GHG inventory to the 1995 baseline GHG inventory in order to assess Keene's progress towards its GHG reduction targets.

2015 Community GHG Inventory

The Community Inventory was completed using the Community Protocol for Accounting and Reporting Greenhouse Gas Emissions (Community Protocol) developed by ICLEI. The Community Protocol provides a national standard in guidance to help U.S. local governments develop effective community GHG emissions inventories. It establishes reporting requirements for all community GHG emissions inventories, provides detailed accounting guidance for quantifying GHG emissions associated with a range of emission sources and community activities, and provides a number of optional reporting frameworks to help local governments customize their community GHG emissions inventory reports based on their local goals and capacities.

Two central categorizations of emissions are used in the community inventory: 1) GHG emissions that are produced by "sources" located within the community boundary, and 2) GHG emissions produced as a consequence of community "activities".

- **Source:** Any physical process inside the jurisdictional boundary that releases GHG emissions into the atmosphere.
- **Activity:** The use of energy, materials, and/or services by members of the community that result in the creation of GHG emissions.

Data for the Community Inventory was obtained from the U.S. Census, the American Community Survey, the U.S. Environmental Protection Agency (EPA), the State of New Hampshire Office of Strategic Initiatives (formerly the Office of Energy and Planning), the Federal Highway Administration, Southwest Region Planning Commission (SWRPC), and others.

2015 Municipal Operations Inventory

The Municipal Inventory was completed using the Local Government Operations Protocol (LGOP) version 1.1 to model emissions from available activity data. The LGOP provides a standard methodology for calculating and reporting emissions from local government operations. It was developed through a partnership of organizations in 2008, including the California Air Resources Board, the California Climate Action Registry, The Climate Registry, and ICLEI. The LGOP allows local governments to compare year-to-year results as well as compare results with other municipalities that follow the LGOP.

The municipal operations inventory categorizes emissions into one of three scopes depending on the degree of control the City of Keene exerts over the source of the emissions.

- **Scope 1:** All direct emissions from a facility or piece of equipment operated by the local government.
- **Scope 2:** Indirect emissions associated with the consumption of purchased or acquired electricity, steam, heating, and cooling.
- **Scope 3:** All other indirect or embodied emissions not covered in Scope 2.

Classifying emissions using the scopes framework helps to prevent double-counting emissions and provides useful information for prioritizing potential GHG mitigation activities. Scope 1 and Scope 2 emissions are the most essential components of a government operations greenhouse gas analysis as they are the most easily affected by local policy.

Data for the Municipal Inventory were gathered from City Departments and from local and regional utility companies, including Eversource, Keene Gas, Discount Oil of Keene, NGL Energy Partners, and Liberty Utilities.

ICLEI Software Tool

Calculations for both the 2015 Community and Municipal Inventories were made using ClearPath, an online emissions management software developed and maintained by ICLEI. Emissions were calculated using activity data (i.e. relevant measurement of energy use or other GHG-generating processes) and emission factors using the following formula:

"Activity Data x Emission Factor x Global Warming Potential = Emissions."

Greenhouse Gases and Output Units

Global Warming Potential (GWP) is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO2). GWPs provide a common unit of measure and are presented in terms of metric tons of CO2 equivalent, or tons CO2e. For example, over 100 years one metric ton of methane has the same effect as 21 metric tons of CO2; therefore the GWP of methane is 21 and 1 metric ton of methane is translated into 21 tons CO2e. This report uses GWP values from the Intergovernmental Panel on Climate Change (IPCC) 2nd Assessment Report, which are provided in Table 1.

Greenhouse Gas	Chemical Formula/ Abbreviation	Global Warming Potential
Carbon Dioxide	CO_2	1
Methane	CH_4	21
Nitrous Oxide	N_2O	310
Hydrofluorocarbons	HCFC	Various
Perfluorocarbons	PFC	Various
Sulfur Hexafluoride	SF_6	23,900

Table 1: IPCC 2nd Assessment global warming potential values.

This inventory assesses emissions of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). In addition, ICLEI recommends that GHG inventories account when possible for high GWP gasses, including hydrofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). High GWP gasses are predominantly emitted from leaks, service, or disposal of refrigerants and from certain industrial processes and equipment used to transmit and distribute electricity. Characterizing emissions from these gases is outside the scope of this analysis.

Comparison of 1995 and 2015 Community Inventory Methodology

The 1995 Community Inventory, which was originally released in 2000, was recalculated in 2009 using version 2.1 of ICLEI's Clean Air and Climate Protection (CACP) software. In addition, the following changes were made to correct, amend, or update the 1995 data in order to more accurately compare 1995 and 2015 values:

- Emissions from the 1995 Transportation Sector were recalculated to ensure the same methodology was used for both inventories.
- Emissions from the solid waste sector were recalculated using ICLEI's ClearPath software in order to account for changes in how emissions for this sector are calculated.

Comparison of 1995 and 2015 Municipal Inventory Methodology

The 2015 Municipal Inventory methodology generally follows that of the 1995 baseline inventory, with a few notable changes. The 1995 Municipal Inventory follows version 1.0 of the LGOP, and all calculations were done using version 2.1 of ICLEI's CACP software. In 2010, version 1.1 of the LGOP was released. This updated version of the LGOP includes updates to emission factors, equations, typographical errors, and example calculations. The following additional changes were made to correct, amend, or update the 1995 data:

- The 1995 vehicle fleet emissions were recalculated using 1995 financial data obtained from the City of Keene archives to provide a more accurate estimate of 1995 vehicle fleet fuel use and emissions.
- Emissions from the 1995 solid waste operations sector were recalculated to account for changes in how emissions for this sector are calculated.

A more detailed methodology, including sector definitions, is included in Appendix A of this report.

2. COMMUNITY INVENTORY

2.1 Overview

The Community Inventory is a community-wide greenhouse gas analysis based on public data that provides estimates of energy use and greenhouse gas (GHG) emissions within the geographic boundary of Keene. The 2015 Community Inventory is divided into four sectors: Transportation, Commercial and Industrial, Residential, and Solid Waste. The proportional breakdown of 2015 emissions by sector is shown in Figure 1.

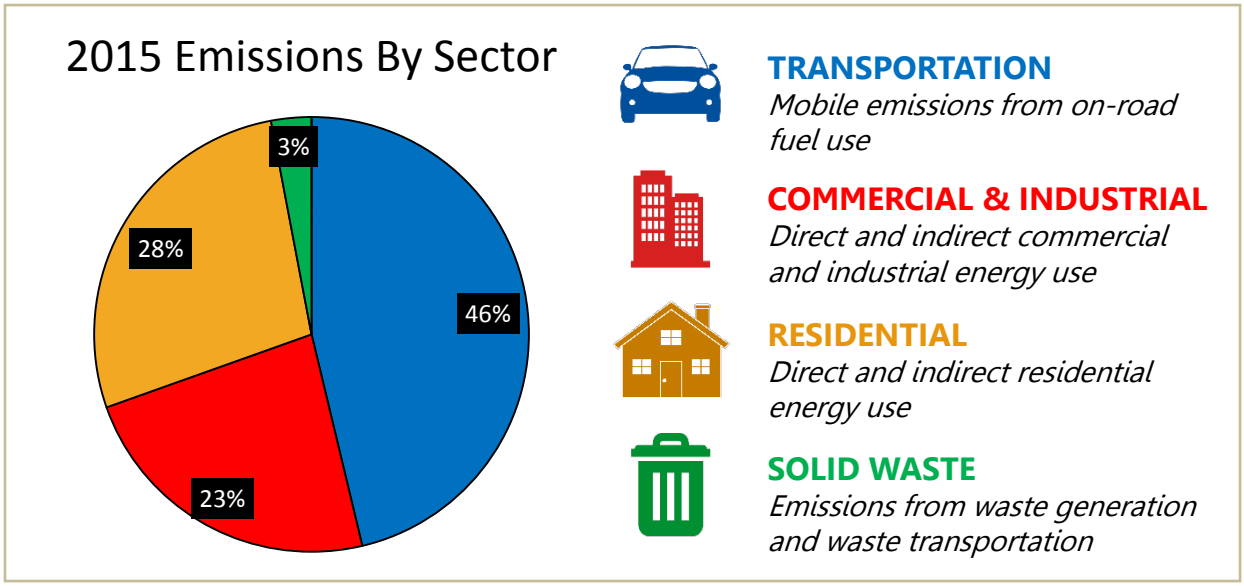


Figure 1: Breakdown of 2015 community-wide emissions by sector for Keene, NH.

In 2015, Keene's community-wide GHG emissions totaled 276,512 tons CO2e, or 11.8 tons CO2e per capita based on 2015 population estimates. Community-wide emissions in 1995 were 284,511 tons CO2e, or 12.5 tons CO2e per capita using 1995 population estimates. This represents a 2.8% decrease in overall emissions and a 5.4% decrease in per-capita emissions from 1995 to 2015, as shown in Table 2. This data indicates that Keene did not reach its GHG emissions reduction target of reducing community-wide emissions to 10% below 1995 levels by 2015.

Per Capita Emissions	1995	2015	Percent Change (%)
Population	22,772	23,403	2.8%
Total Emissions (tons CO2e)	284,511	276,512	-2.8%
Per Capita Emissions (tons CO2e/person)*	12.49	11.82	-5.4%

Table 2: Comparison of 1995 and 2015 values for total population, total emissions, and per capita emissions for the Keene Community Inventory. **Figures may not be exact due to rounding.*

Figure 2 below shows the total emissions for the Community Inventory in 1995 and 2015 broken down by sector. It also includes the 2015 emissions reduction target to visually show the difference between 2015 actual emissions and the 2015 target emissions. Table 3 provides the community-wide emissions by sector, in tons CO2e, for 1995 and 2015 and the percent change in emissions.

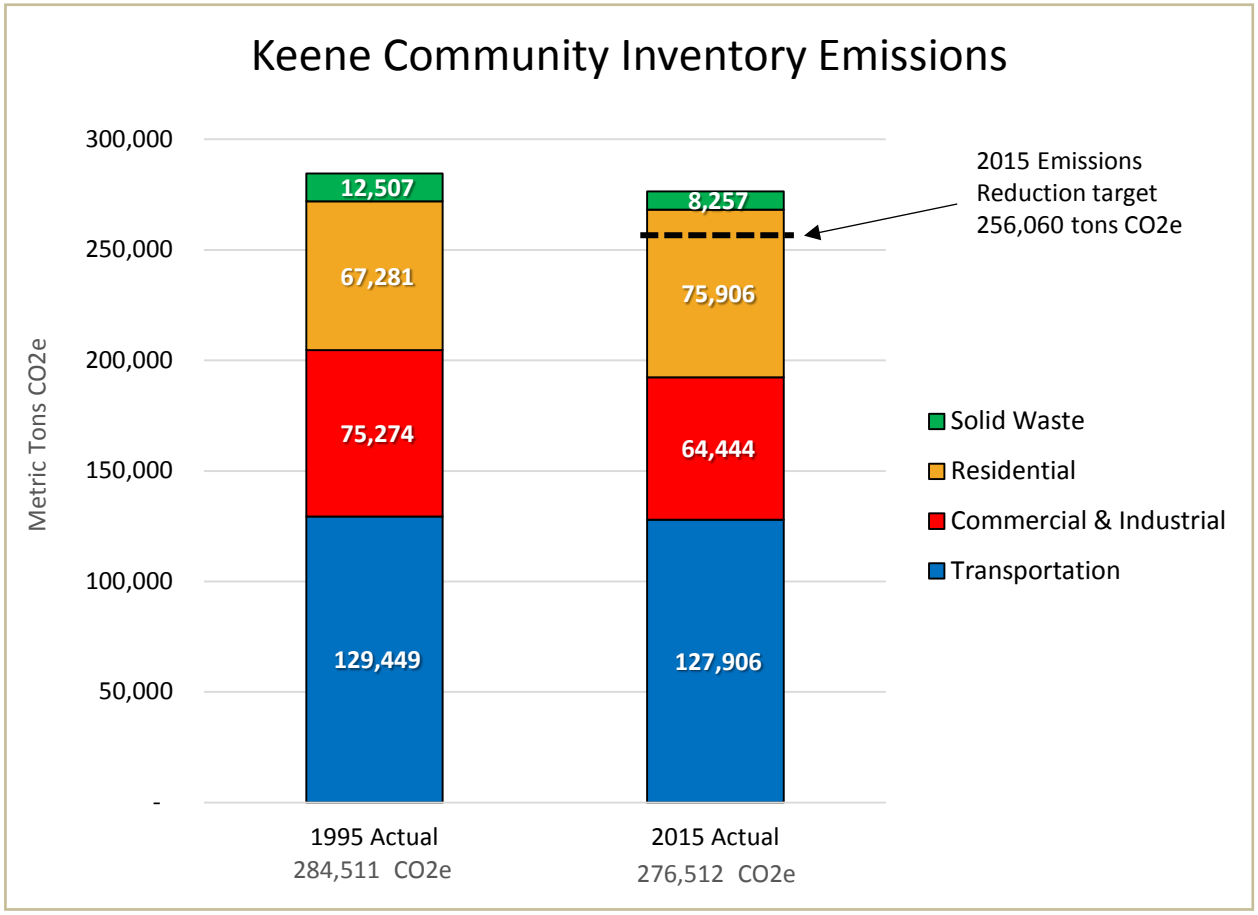


Figure 2: Total community-wide emissions in 1995 and 2015 and 2015 emissions reduction target for Keene, NH.

Community Inventory Emissions By Sector	1995 Emissions (tons CO2e)	2015 Emissions (tons CO2e)	Percent Change (%)
Transportation	129,449	127,906	-1.2
Commercial & Industrial	75,274	64,444	-14.4
Residential	67,281	75,906	12.8
Solid Waste	12,507	8,257	-34.0
Total	**284,511**	**276,512**	**-2.8**

Table 3: Comparison of 1995 and 2015 community-wide GHG emissions for Keene, NH.

2.2 Emissions by Sector

A. Transportation Sector

The transportation sector continues to be the largest contributor to GHG emissions for the community, representing 46% of community-wide emissions in both 1995 and 2015. Total emissions for the transportation sector in 2015 were 127,905 tons CO2e, or 5.5 CO2e per capita. In 1995, total emissions were 129,449 tons CO2e, or 5.7 tons CO2e per capita. This represents a 1% and 4% decrease, respectively. Table 4 provides the total energy use, emissions, emissions per capita and total vehicle miles traveled (VMT) for the Transportation Sector in 1995 and 2015.

Transportation Sector Definition

The transportation sector includes on-road emissions from passenger vehicles, freight and public transit that occur within the jurisdictional boundary of Keene. This analysis does not incorporate air travel emissions. Information about the methodology used to calculate transportation sector emissions is included in Appendix A of this document along with air travel data.

It is interesting to note that while energy use and emissions stayed relatively constant, the total VMT increased by almost 26% from 1995 to 2015. This suggests that gains in the average fleet fuel economy have more than offset the increase in VMT during this time period, resulting in lower emissions despite the increase in traffic volumes.

The majority of transportation emissions in 2015 were generated by on-road gasoline use (84%) followed by on-road diesel use (16%). Only a small fraction of transportation emissions, about 0.1%, are attributable to the City Express bus service and the Friendly Bus Service operated by Home, Healthcare, Hospice and Community Services (HCS). Figure 3 shows the emissions from gasoline use and diesel use for 1995 and 2015.

	1995	2015	Percent change
Energy use (MMBTU)	1,757,869	1,771,410	1%
Emissions (tons CO2e)	129,449	127,906	-1%
Emissions per capita*	5.7	5.5	-4%
Total VMT (millions)	211.2	265.6	26%

Table 4: Transportation Sector energy use, emissions, emissions per capita, and total VMT in 1995 and 2015. **Figures may not be exact due to rounding.*

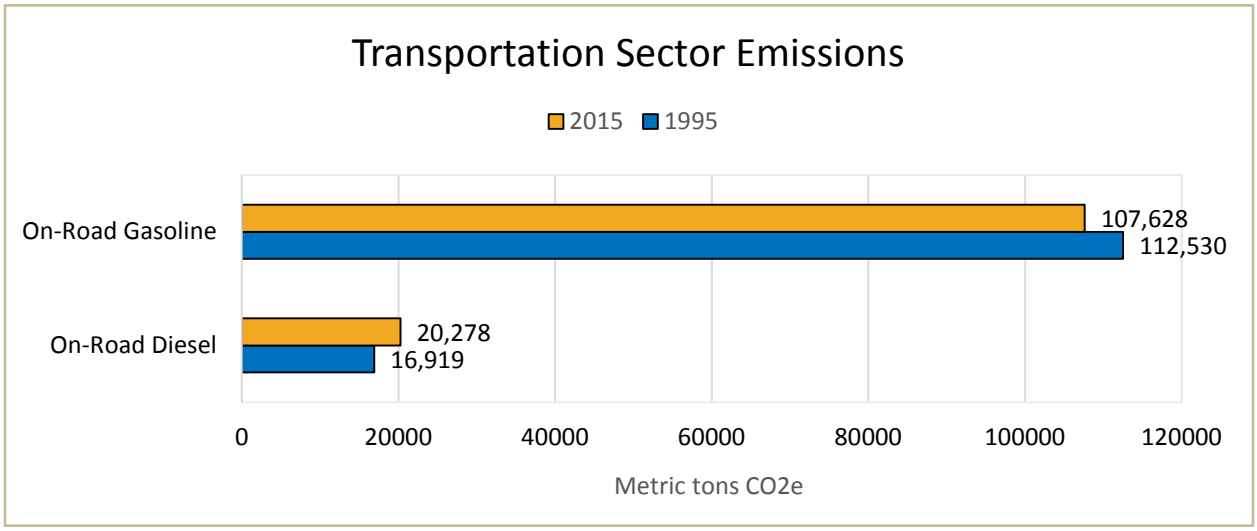


Figure 3: Transportation Sector emissions in 1995 and 2015 by fuel source.

In general, transit ridership in Keene has been decreasing since 2008 and 2009, when it peaked at 65,317 total trips for the two bus services combined. However, ridership in 2014-2015 was still significantly higher than ridership in 1994-1995, as shown in Figure 4. In the 1994-1995 season, combined ridership was 34,248 trips, whereas in the 2014-2015 season it was 54,939 trips, representing a 60% increase.

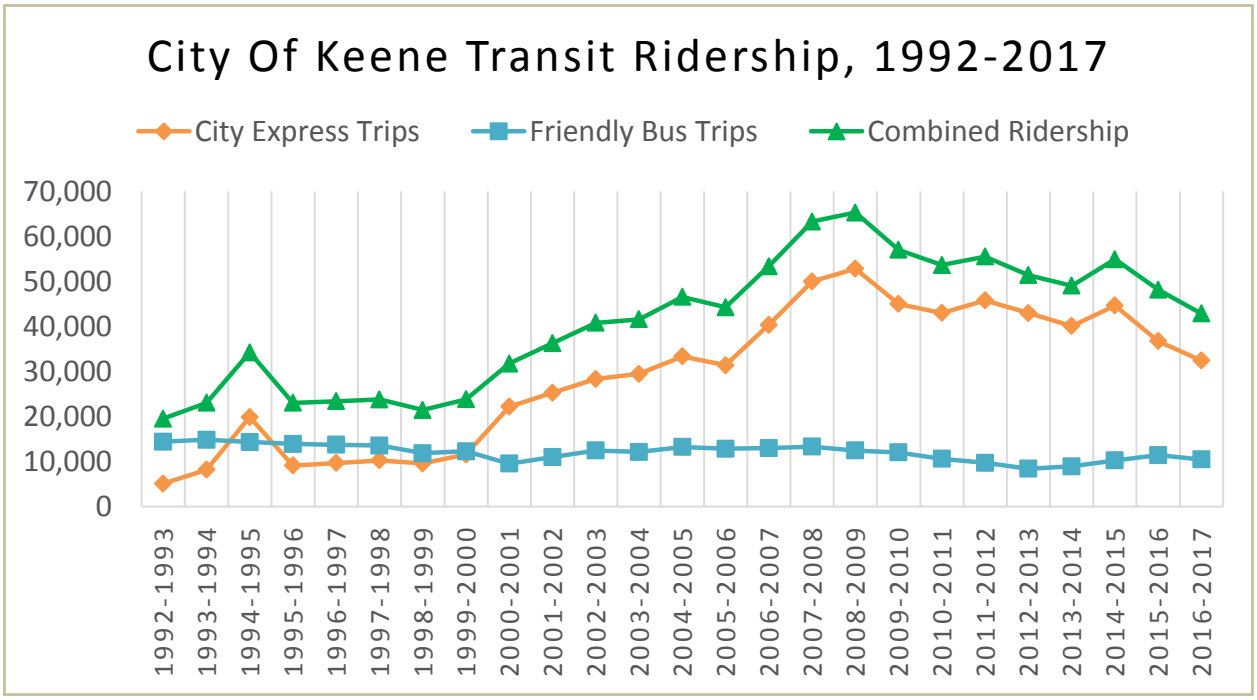


Figure 4: City of Keene transit ridership from 1992-2017. Source: HCS.

B. Commercial & Industrial Sector

Total emissions for the commercial and industrial sector in 2015 were 64,444 tons CO2e and total energy use was 551,871 MMBtu, representing a 14% and 35% decrease from 1995 values, respectively. During this same time period, over 1 million square feet of commercial and industrial space was built in Keene, resulting in a 31% decrease in emissions per square foot. This decrease in energy use and emissions may be partially explained by fuel switching (mostly from #2 fuel oil to piped propane gas), changes in the electricity mix in NH, increases in building efficiency, and the impact of weather conditions on energy use from year to year (i.e. heating degree days and cooling degree days).

Table 5 shows the change in total energy use (MMBtu), total emissions (tons CO2e), and emissions per square foot of commercial space from 1995 to 2015. Figure 5 shows the breakdown of emissions from the commercial sector by source for 2015, and Figure 6 compares 1995 and 2015 emissions by energy source.

Commercial & Industrial Sector Definition

The Commercial and Industrial sector includes electricity and fuel usage for commercial and industrial (i.e. non-residential) institutions located within the City of Keene. Emissions from the use of kerosene and residual (#6) fuel oil were not considered in this analysis. Emissions associated with the use of kerosene and residual fuel oil are reported in Appendix A of this document.

	1995	2015	Percent Change
Energy Use (MMBtu)	847,686	551,871	-35%
Emissions (tons CO2e)	75,274	64,444	-14%
Emissions per sq. foot	0.017	0.012	-31%

Table 5: Commercial and Industrial Sector energy use, emissions, and emissions per square foot in 1995 and 2015.

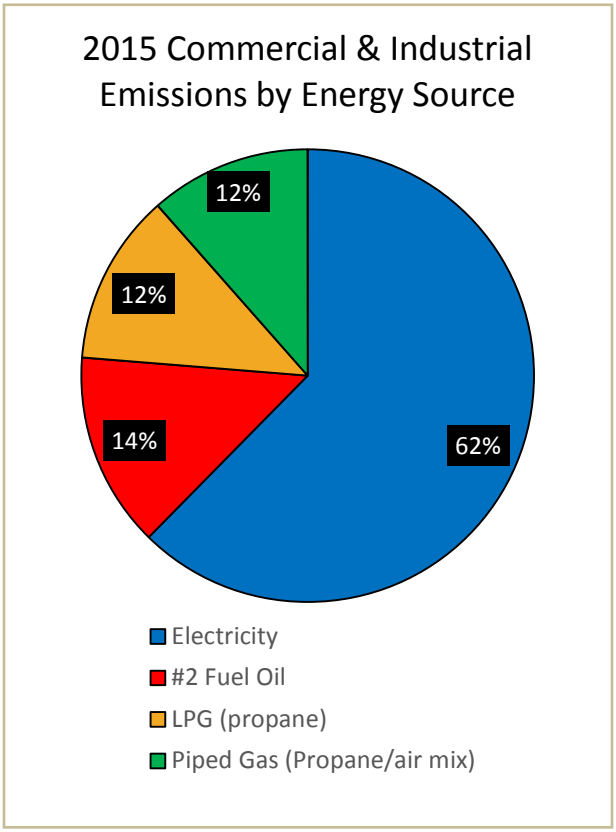


Figure 5: Breakdown of 2015 Commercial and Industrial Sector Emissions by energy source.

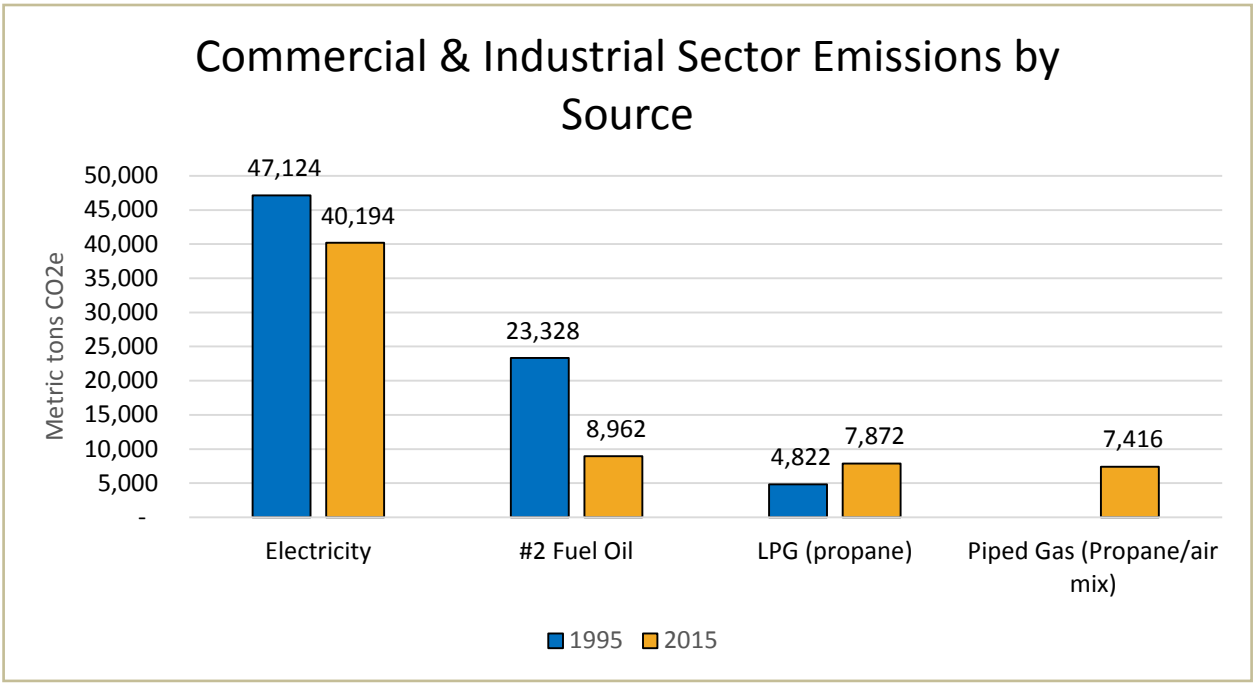


Figure 6: 1995 and 2015 Commercial and Industrial Sector Emissions by energy source.

In 2015, the Commercial and Industrial Sector relied less on oil and more on propane (LPG and piped gas), which accounts for some of the reduction in emissions for this sector. According to the US Energy Information Administration (EIA), propane produces about 139 pounds of CO2 per MMBTU whereas fuel oil produces 161.3 pounds per MMBTU. Thus, switching from fuel oil to propane results in fewer carbon dioxide emissions. Commercial and industrial emissions from electricity use decreased by about 15% from 1995 to 2015. This is partly due to cleaner energy supplying the electrical grid in New England, and partly due to energy use reductions from increased energy efficiency.

Energy use within the Commercial and Industrial Sector is also affected by the number of days that require heating or cooling throughout the year. According to data from the National Oceanic and Atmospheric Administration (NOAA), there were 219 fewer "heating degree days" (HDD) in Keene in 2015 than in 1995. HDD is the number of degrees that a day's average temperature is below 65˚F, the temperature below which buildings need to be heated. It is a measure of how much (in degrees), and for how long (in days), the outside air temperature was below 65˚F and it is commonly used in calculations relating to the energy consumption required to heat buildings and to compare energy use between two different periods of time.

The difference in HDD suggests that some of the decrease in energy use is attributable to warmer weather in 2015. However, some of the difference in energy use may be due to increases in energy efficiency. In 1995, the commercial and industrial sector used about 111 MMBTUs of energy equivalent per HDD, whereas in 2015 the sector used about 74.1 MMBTUs per HDD, as shown in Table 6. The column to the far right of Table 6 shows normalized equivalents of the original MMBTU figures based on the average number of HDD per year in Keene from 1995-2015.

Similarly, "cooling degree days" (CDD) is a measure of how much (in degrees) and for how long (in days) the outside temperature was above 65 degrees Fahrenheit, the temperature above which buildings need to be cooled. According to the NOAA, there were 137 more CDD in 2015 than in 1995. The MMBTU per CDD in 1995 was 2,374 and in 2015 it was 1,117, as shown in Table 7. The column to the far right gives normalized equivalents of the original MMBTU figures based on the average number of CDD per year in Keene from 1995-2015.

Year	Total Energy Use (MMBTU)	Total heating degree days	MMBTU per degree day*	Normalized MMBTU
1995	847,687	7,666	111	790,571
2015	551,871	7,447	74	529,823

Table 6. Total energy use, total heating degree days (HDD), energy use per HDD, and normalized energy use in 1995 and 2015. ***Figures may not be exact due to rounding.***

Year	Total Energy Use (MMBTU)	Total cooling degree days	MMBTU per degree day*	Normalized MMBTU
1995	847,687	357	2,374	1,074,012
2015	551,871	494	1,117	505,304

Table 7. Total energy use, total cooling degree days (CDD), energy use per CDD, and normalized energy use in 1995 and 2015. ***Figures may not be exact due to rounding.***

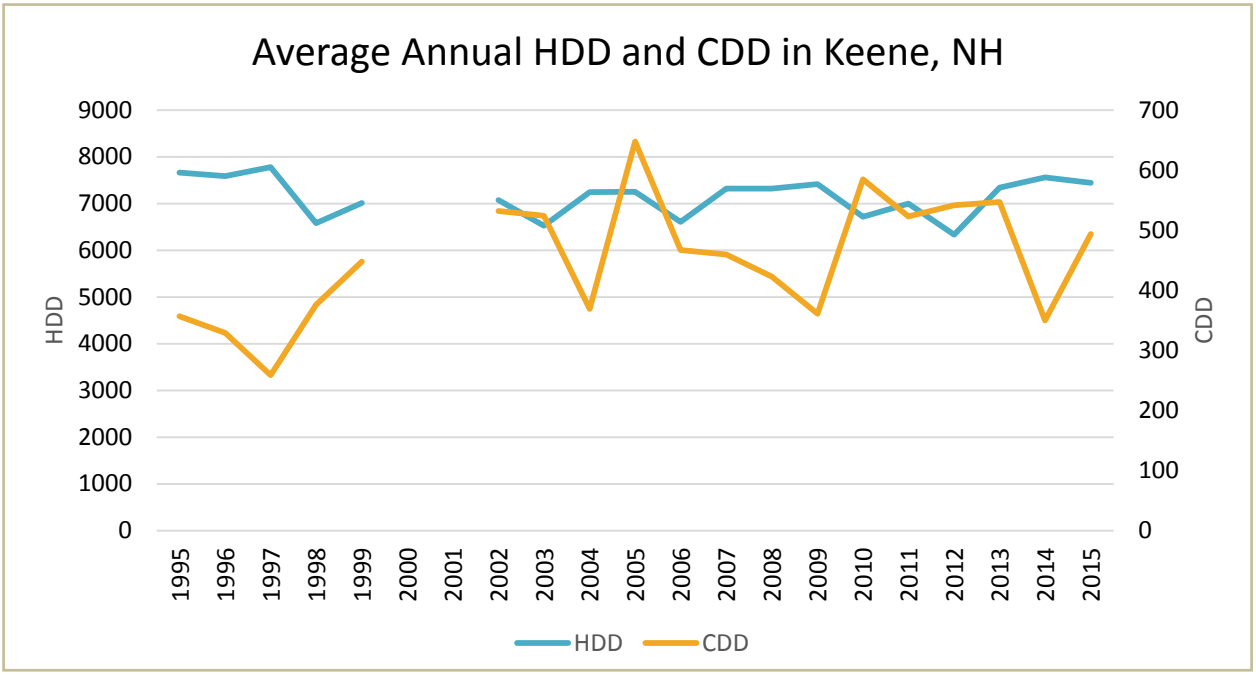


Figure 7. Average annual HDD and CDD in Keene, NH from 1995-2015. Data from 2000 and 2001 are omitted because data sets were incomplete. Source: NOAA.

C. Residential Sector

Total emissions for the Residential Sector in 2015 were 75,906 tons CO2e and total energy use was 950,842 MMBTU. In 1995, total emissions for the Residential Sector were 67,281 tons CO2e and total energy use was 791,615 MMBTU. This represents a 13% increase in overall emissions and a 20% increase in energy use from 1995 to 2015, as shown in Table 8. Per household, energy use increased from 89 to 100 MMBTUs and emissions increased from 7.6 to 8.2 tons CO2e, a 12% and 9% increase, respectively.

Residential Sector Definition

The Residential Sector includes GHGs associated with the energy consumed by Keene's residential buildings for lighting, appliances, heat, and hot water. Emissions from the use of kerosene and wood were not included in this analysis. Emissions associated with the use of kerosene and wood are reported in Appendix A of this document.

Figure 8 shows the breakdown of emissions by energy source for the Residential Sector in 2015. Almost half (46%) of all Residential Sector emissions are due to electricity use, followed by #2 fuel oil (34%), and propane (18% LPG and 2% piped propane/air mix).

	1995	2015	Percent Change
Energy use (MMBTU)	791,615	950,842	20%
Emissions (tons CO2e)	67,281	75,906	13%
Total households	8864	9208	4%
Energy use/ household*	89	100	12%
Emissions/ household*	7.6	8.2	9%

Table 8: Residential Sector energy use, emissions, and emissions per household in 1995 and 2015.
Figures may not be exact due to rounding.

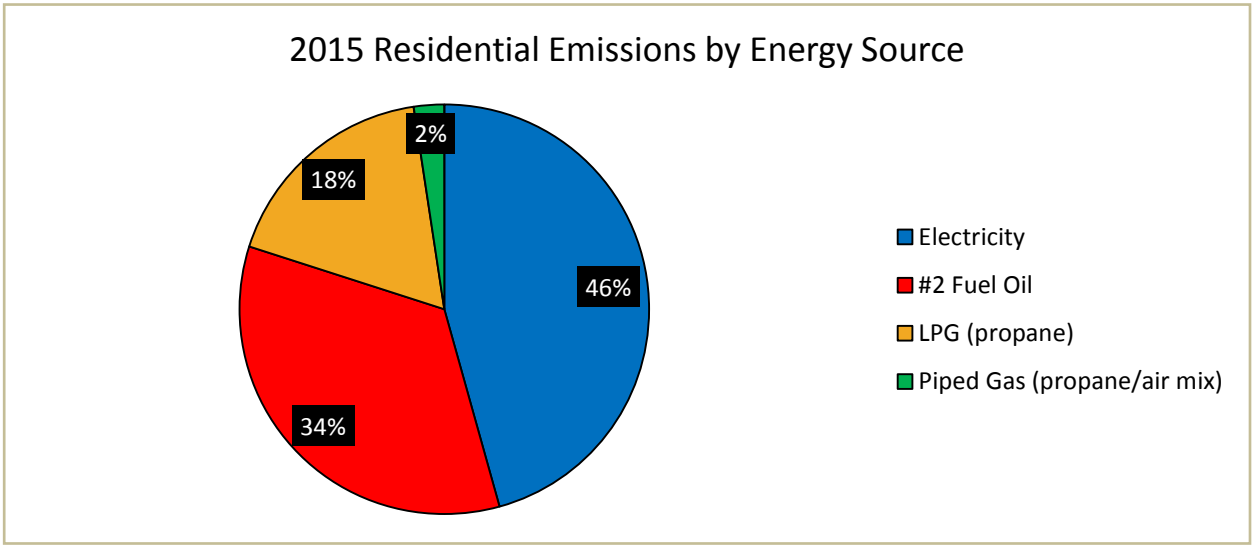


Figure 8: Breakdown of 2015 Residential Sector Emissions by energy source.

The increase in energy use and emissions within the Residential Sector between 1995 and 2015 is likely due in large part to an increase in the use of household appliances and electronics. Figure 9 indicates that emissions from electricity use increased by 90% over this time period.

According to the EIA Residential Energy Consumption Survey (RECS), the percentage of US home energy consumption due to appliances has been increasing as more households are using more major appliances such as refrigerators, air conditioners, clothes washers, and dishwashers. Between 1993 and 2009, the percent of household energy consumption from household appliances, electronics, and lighting increased from 24% to 34.6%. It is likely that this trend has continued since 2009 with the increase in personal electronics, including smart phones and other devices, that has occurred since then. The EIA notes that, while the overall efficiency of some appliances that are subject to federal efficiency standards such as refrigerators and clothes washers have become more efficient, the increased number of devices that consume energy in homes has more than offset these efficiency gains.

Similar to the Commercial and Industrial Sector, the results of the Community Inventory indicate that there has been a shift among the Residential Sector from #2 fuel oil to propane (LPG and piped gas), which is a less carbon-intensive fuel. Again, according to the EIA, propane produces about 139 pounds CO2 per MMBTU whereas fuel oil produces 161.3 pounds per MMBTU. Residential Sector emissions from fuel oil decreased by 44%, while emissions from propane use went up almost 400%, a 4-fold increase.

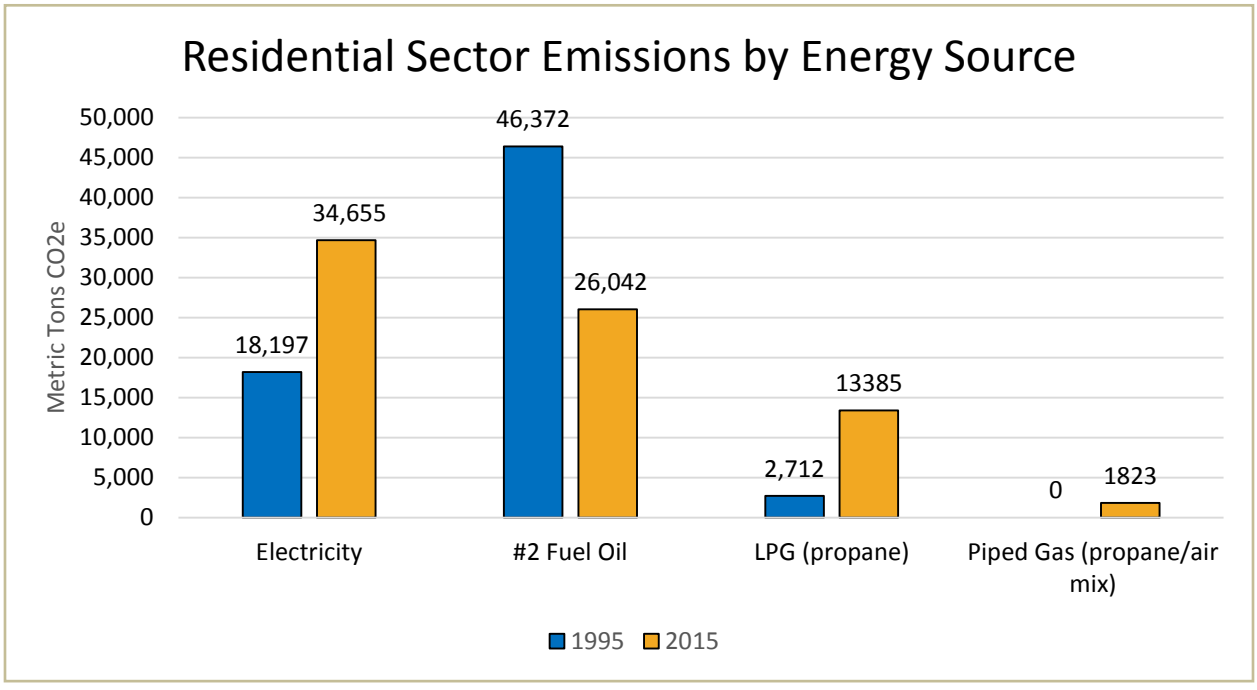


Figure 9: 1995 and 2015 Residential Sector Emissions by energy source.

D. Solid Waste Sector

Solid Waste Sector emissions decreased from 12,507 tons CO2e in 1995 to 8,257 tons CO2e in 2015, representing a 34% decrease emissions. Emissions per capita correspondingly decreased from 0.6 to 0.4 tons CO2e, representing a 36% decrease. The majority of Solid Waste Sector emissions, about 97%, come from waste generation, as shown in Figure 10. The remaining 3% of emissions result from trucking the waste to the Turnkey Landfill in Rochester, NH, a distance of 92 miles. In 1995, there were no emissions associated with trucking the waste outside the jurisdiction because all of Keene's waste was sent to the Keene municipal landfill.

In 1995, Keene generated 32,162 tons of solid waste, whereas in 2015 the community generated 22,169 tons of solid waste, representing a 31% decrease in overall waste generation and a 36% decrease in waste generation per capita. Table 9 provides the solid waste emission and waste generation figures and percent change for 1995 and 2015.

	1995	2015	Percent Change
Total emissions (tons CO2e)	12,507	8,257	-34%
Tons waste generated	32,162	22,169	-31%
Emissions per capita	0.6	0.4	-36%
Tons waste per capita	1.4	0.9	-33%

Table 9: Solid Waste Sector emissions and waste generation figures for 1995 and 2015.

Solid Waste Sector Definition

The Solid Waste sector includes emissions associated with waste generated by the community in 2015. This inventory estimates the total quantity of fugitive methane expected from the waste disposed in the inventory year, throughout its entire decay process in the landfill. The decay process occurs partly during the inventory year and partly during future years, however all methane emissions are attributed to the year in which the waste was disposed. This sector also includes emissions from trucking the solid waste to the Turnkey Landfill in Rochester, NH. Transportation emissions associated with the collection of municipal solid waste by waste collection companies are assumed to be captured in the transportation sector analysis of this report. This assumption avoids double counting transportation-related emissions from municipal solid waste in the community-wide totals.

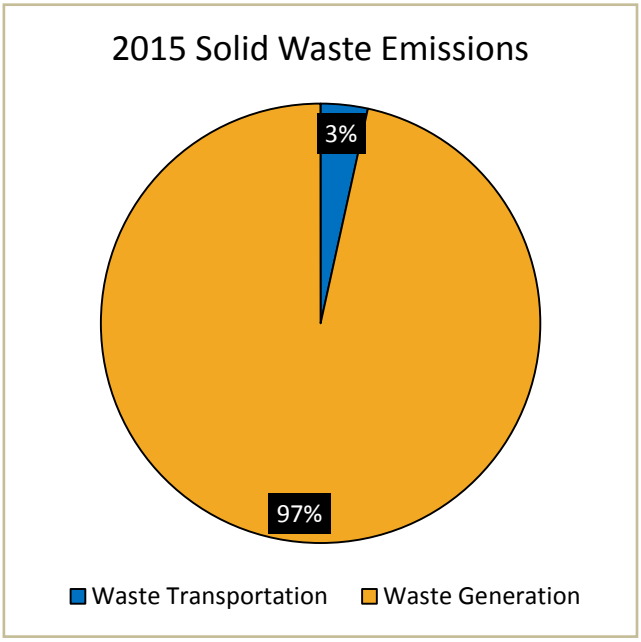


Figure 10: 2015 Solid Waste Sector emissions.

An analysis of avoided emissions from the City of Keene's residential recycling and yard compost programs is outside the scope of this report, however it is assumed that these programs have played a significant role in the reduction of Keene's per-capita waste generation. According to a 1996 report prepared for the City of Keene, a large portion of the residential waste stream in 1995 was comprised of recyclable materials. For example, the report estimates that 37% of the residential waste stream in 1995 was paper products and 18% was yard trimmings. It is reasonable to assume that some of this waste has been diverted to recycling and yard composting.

Both the Keene Municipal Landfill and the Turnkey Landfill in Rochester, NH have landfill gas (LFG) capture systems in place to capture LFG and convert it to usable energy. These systems are estimated to have avoided a total of 37,519 tons CO2e in 1995 and 23,914 tons CO2e in 2015, as shown in Figure 11.

How is Landfill Gas (LFG) Produced?

Landfill gas (LFG) is a natural byproduct of the decomposition of organic material in landfills. Organic material such as paper, food scraps, and yard trimmings is initially decomposed by aerobic bacteria in the landfill. Once the available oxygen has been depleted, anaerobic, non-methanogenic bacteria further decompose the organic waste. These substances are then broken down through fermentation into gases and organic compounds, which are then converted by methanogenic bacteria into landfill gas (LFG). LFG is composed of roughly 50 percent methane (the primary component of natural gas), 50 percent carbon dioxide (CO2) and a small amount of non-methane organic compounds. The methane produced through this process is often referred to as "fugitive methane emissions."

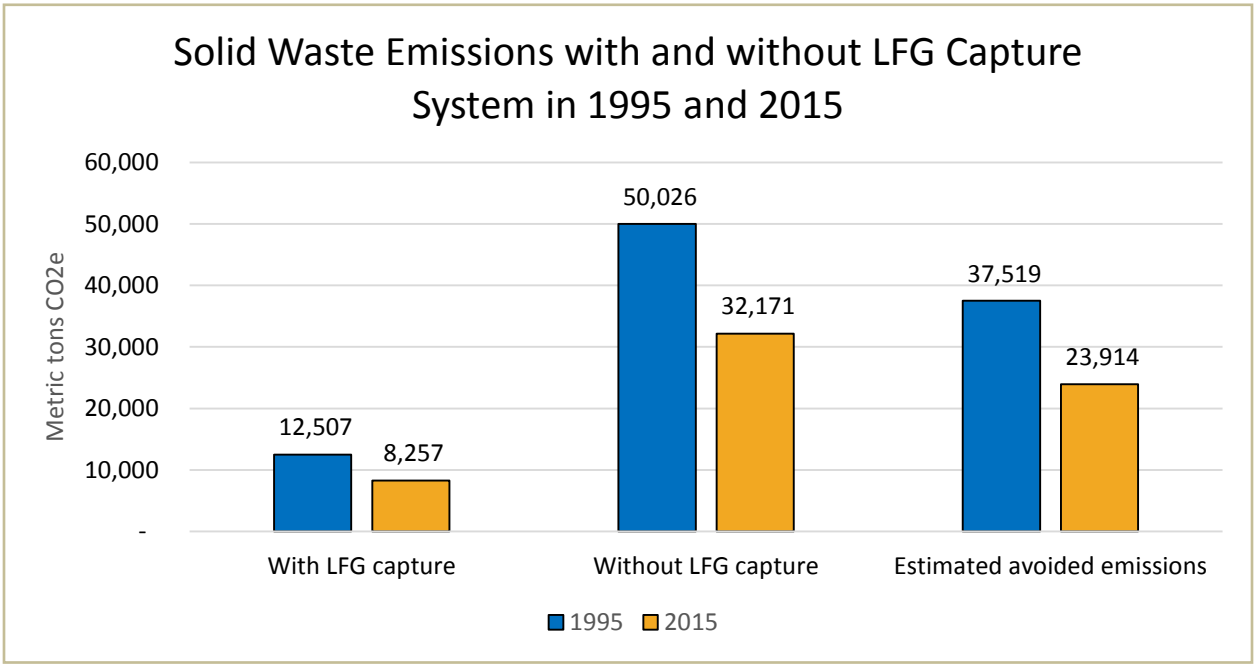


Figure 11: Solid Waste Sector emissions with and without a landfill gas (LFG) capture system in place and estimated avoided emissions due to the present of LFG capture systems at the Keene Municipal Landfill and the Turnkey Landfill.

3. MUNICIPAL INVENTORY

3.1 Overview

The Municipal Inventory analysis accounts for emissions generated from operations managed directly or contracted by the City of Keene in 2015. The Municipal Inventory is split into six sectors: Buildings and Facilities, Vehicle Fleet, Wastewater Treatment, Water Delivery, Streetlights and Traffic Signals, and Airport Operations. Emissions from municipal solid waste operations are reported in section 4 of this report on page 31. Figure 12 shows the breakdown of emissions for the 2015 municipal analysis by sector, and Table 10 provides the total emissions by sector for 1995 and 2015 and the percent change in emissions.

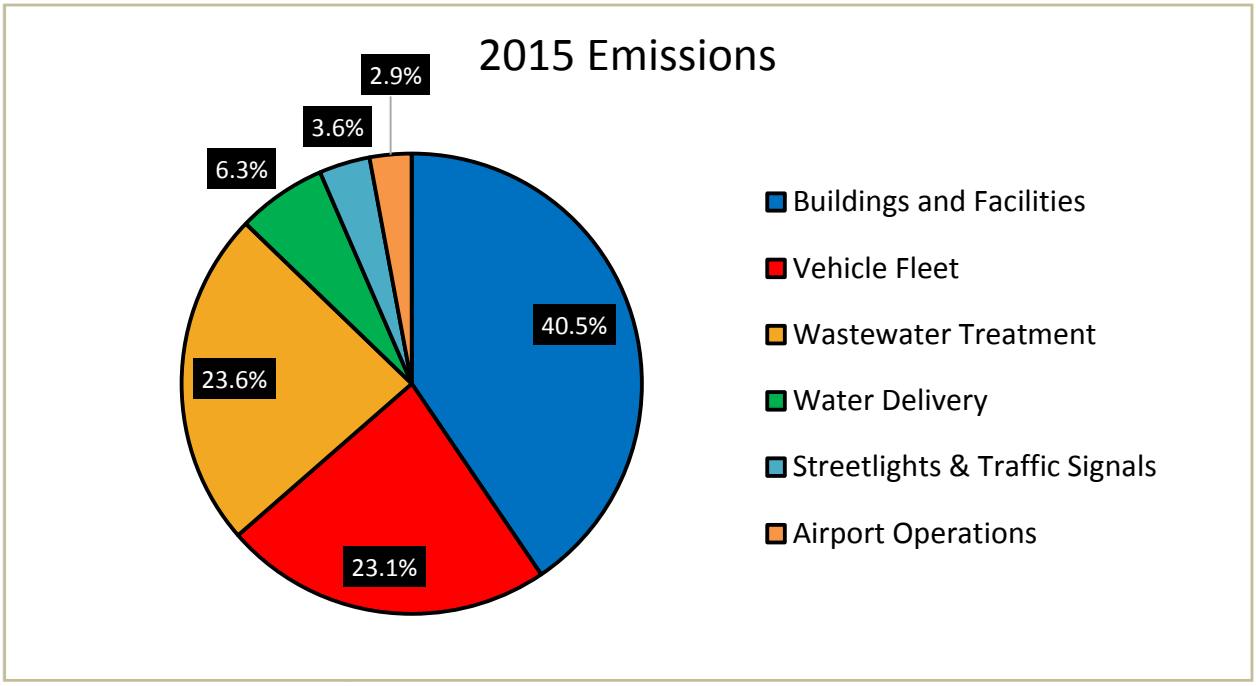


Figure 12: Breakdown of 2015 municipal emissions by sector for the City of Keene, NH.

	1995 Emissions (tons CO2e)	2015 Emissions (tons CO2e)	Percent Change
Buildings and Facilities	2,578	1,784	-31%
Vehicle Fleet	989	1,016	3%
Wastewater Treatment	1,644	1,041	-37%
Water Delivery	223	276	24%
Streetlights & Traffic Signals	254	158	-38%
Airport Operations	211	129	-39%
Total	**5,899**	**4,423**	**-25%**

Table 10: Municipal Inventory emissions by sector for 1995 and 2015 and percent change in emissions.

In 2015, Keene's municipal GHG emissions totaled 4,423 tons CO2e, representing a 25% decrease from 1995 emissions. Figure 12 shows the total emissions for the Municipal Inventory in 1995 and 2015. Figure 12 also includes the 2015 emissions reduction target to visually show the difference between 2015 actual emissions and the 2015 target emissions. This data indicates that Keene exceeded its GHG emissions reduction target of reducing municipal emissions to 20% below 1995 levels by 2015.

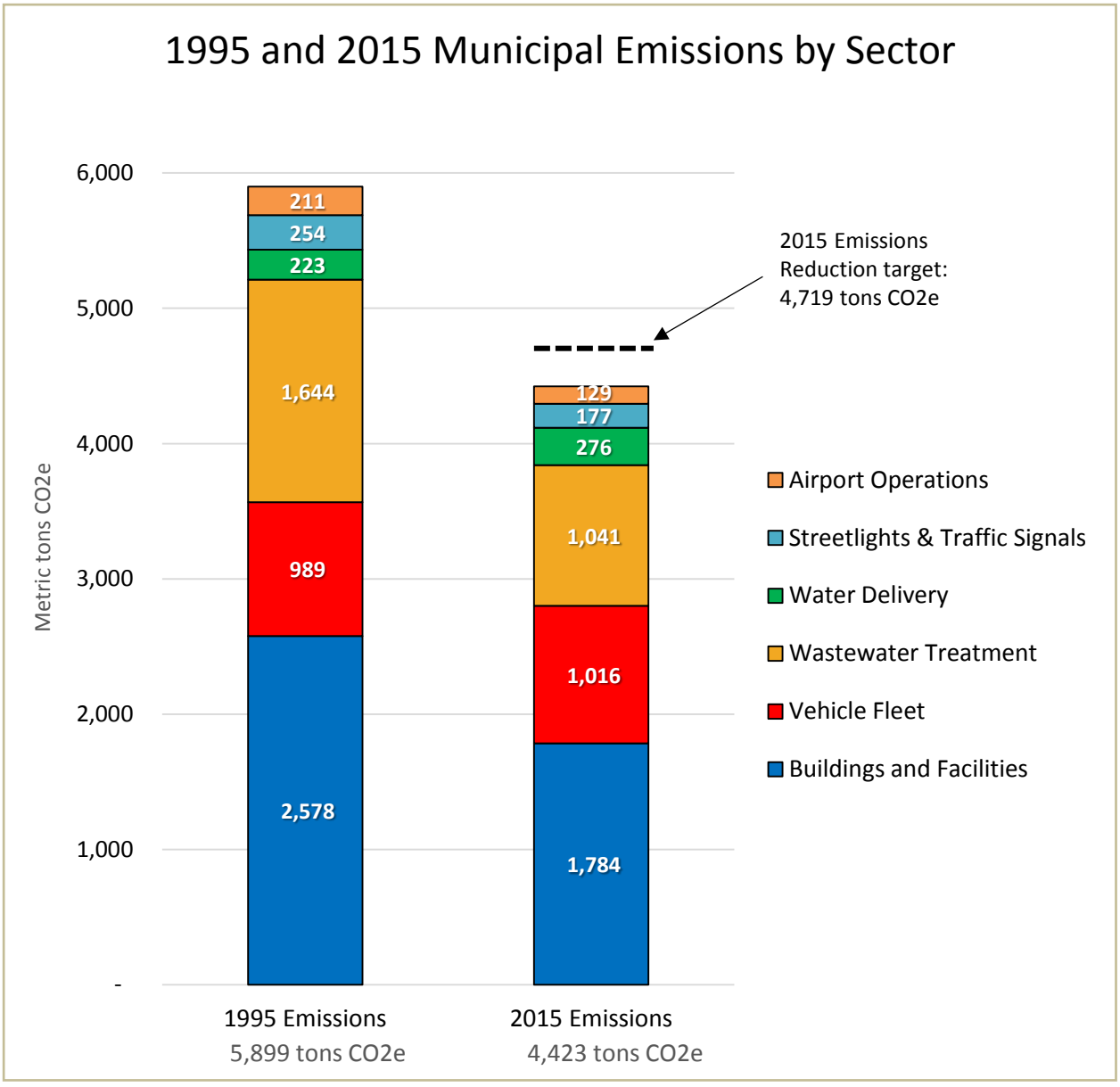


Figure 13: Breakdown of 1995 and 2015 municipal emissions by sector for the City of Keene, NH. The dashed line indicates the emissions reduction target for municipal GHG emissions, which was 20% below 1995 levels, or 4,719 tons CO2e if emissions from the Solid Waste Sector are excluded.

3.2 Emissions by Sector

A. Buildings and Facilities

Emissions from municipal buildings and facilities decreased from 2,578 tons CO2e in 1995 to 1,784 tons CO2e in 2015, representing a 31% decrease, and energy use went from 29,785 MMBTU to 23,708 MMBTU, representing a 20% decrease. Over this same time period, the City added a net total of over 245,000 square feet of building space for municipal use. The majority of the emissions reductions from the Buildings and Facilities Sector are due to a reduction in fuel oil use, as shown in Figure 14.

Buildings and Facilities Sector Definition

The Buildings and Facilities Sector includes electricity and fuel use for all municipal buildings that are under the City's operational control and are not specifically included in any other sector. School buildings are not included in this sector. Water delivery, wastewater, airport, and solid waste facilities (i.e. Transfer Station and Recycling Center) are included in separate sectors.

Some of the reduction in fuel oil use may be due to warmer weather in 2015, which had 219 fewer heating degree days than in 1995, however the City of Keene implemented a variety of energy efficiency measures between 1995 and 2015 which has likely had a significant impact on energy use within this sector. For example, in 2011 the City entered into an energy services contract to upgrade City buildings, which included lighting efficiency improvements, building envelope improvements, and energy management controls and system improvements, among other measures. According to a 2016 report provided to the City of Keene by Honeywell Energy Services, these measures are expected to save 683 tons of CO2e per year and are estimated to have an avoided cost of $246,056 between October 2014 and September 2015.

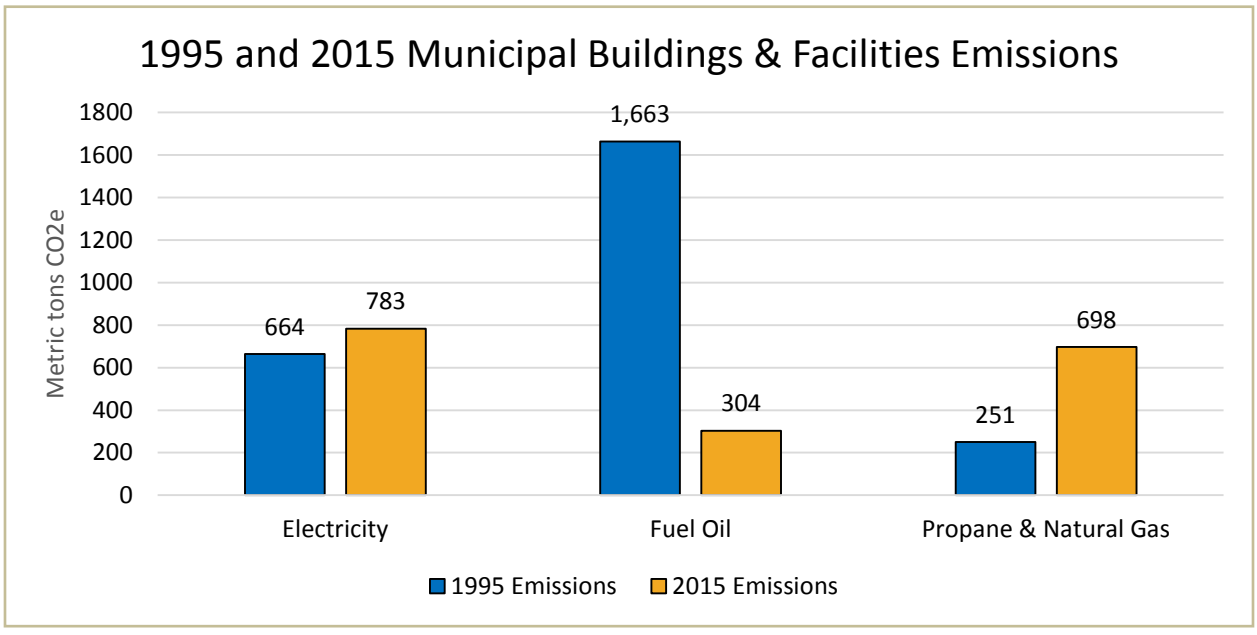


Figure 14: 1995 and 2015 Municipal Buildings and Facilities Sector emissions by energy source.

B. Vehicle Fleet

Emissions from the City's vehicle fleet went from 989 tons CO2e in 1995 to 1,016 tons CO2e in 2015, representing a 3% increase. According to the City of Keene Department of Public Works, the overall number of vehicles has stayed relatively constant over time. Thus, the emissions per vehicle are expected to be about the same in 1995 and 2015.

In 1995, all of the City's fleet vehicles used either unleaded gasoline or diesel fuel. In 2015, the City used a 20% biodiesel blend (B20) which replaced the majority of its diesel use, as shown in Figure 15. The use of B20 fuel in 2015 is estimated to have avoided about 111 tons CO2e. In addition, in 2005 the City began using hybrid vehicles in the City fleet. Calculating avoided emissions from the use of these vehicles was outside the scope of this report, however it is expected that the use of hybrid vehicles has helped to reduce fuel use and emissions from this sector.

Vehicle Fleet Sector Definition

The municipal fleet is the mobile portion of the City of Keene's fleet operations. This definition excludes the stationary facilities used to support Keene's municipal fleet; these facilities are included in the Buildings sector. It is important to note that the 2015 emissions were calculated directly using fuel use data provided by the City of Keene Fleet Services, whereas the 1995 emissions were estimated indirectly using financial data from the City of Keene's archives, which were the most accurate data available for that year. It is possible that the 1995 vehicle fleet emissions were under-reported using this method. A detailed description of the methodology is included in Appendix A of this report.

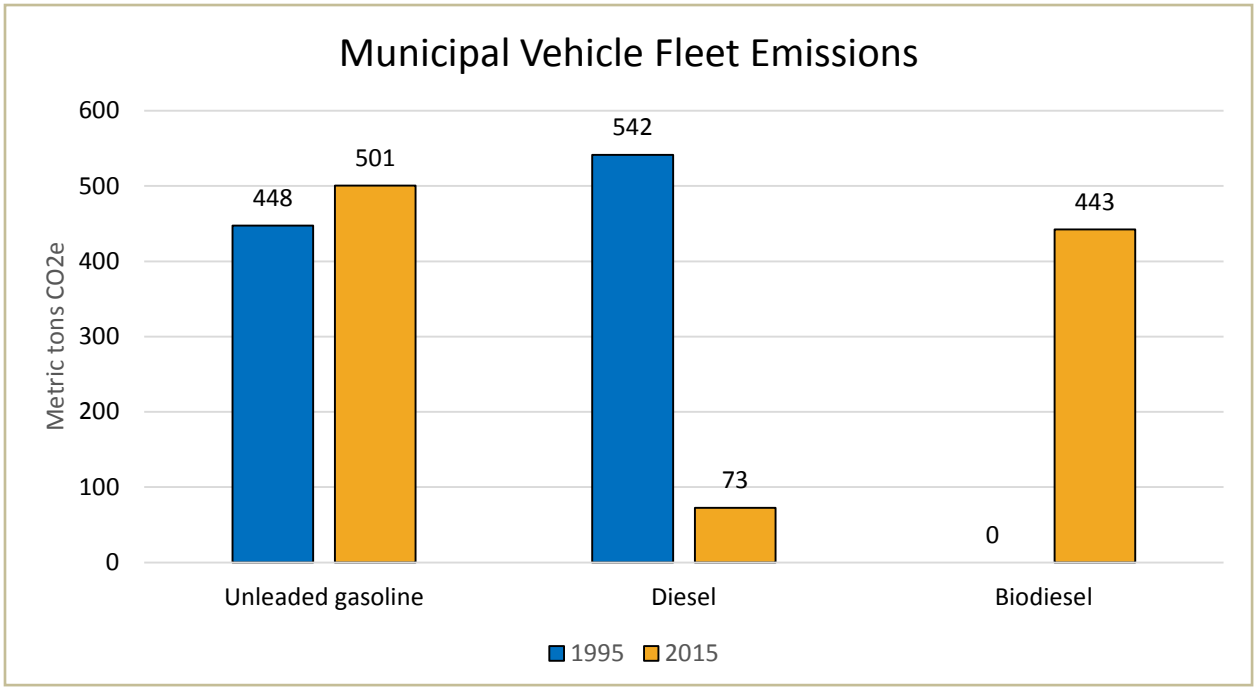


Figure 15: 1995 and 2015 Vehicle Fleet Sector emissions by fuel source

C. Wastewater Treatment

Emissions from the Wastewater Treatment Sector went from 1,644 tons CO2e in 1995 to 1,041 tons CO2e in 2015, representing a 37% decrease in emissions. Figure 16 shows the breakdown in emissions by source, and Figure 17 shows the breakdown in emissions by facility type.

The majority of emissions from this sector, about 72%, are associated with electricity used to power the Wastewater Treatment Plant (WWTP), the Martel Court pump station, and operate the sewer system. Process nitrous oxide (N2O) emissions resulting from the nitrification process and effluent discharge to the Ashuelot River accounted for 22% of emissions in 2015, and propane use accounted for 6% of emissions.

Wastewater Treatment Sector Definition

The Wastewater Treatment Sector includes emissions associated with the Wastewater Treatment Plant (WWTP) located at 420 Airport Road, the operation of the Martell Court pump station, and the operation of the municipal sewer system. Emissions associated with the WWTP include electricity and propane to power and heat the building and equipment as well as process N2O emissions resulting from nitrification and effluent discharge into the Ashuelot River.

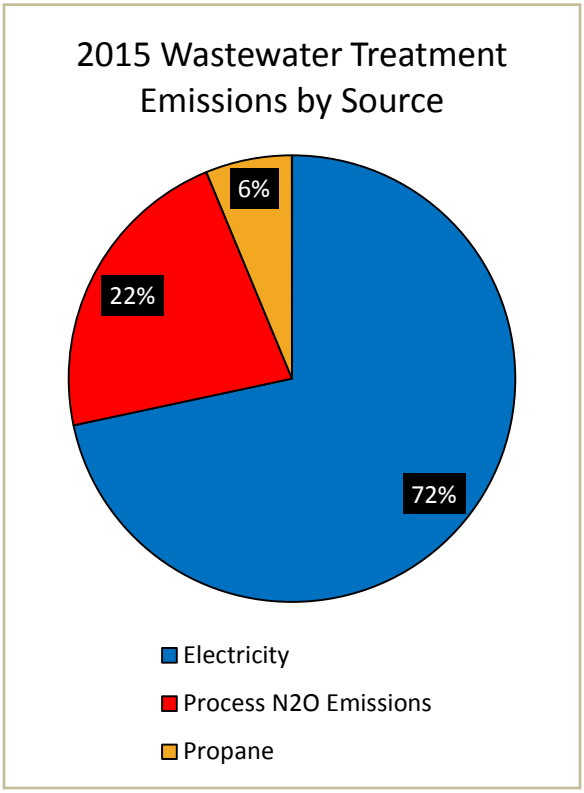


Figure 16: 2015 Municipal wastewater treatment emissions by source.

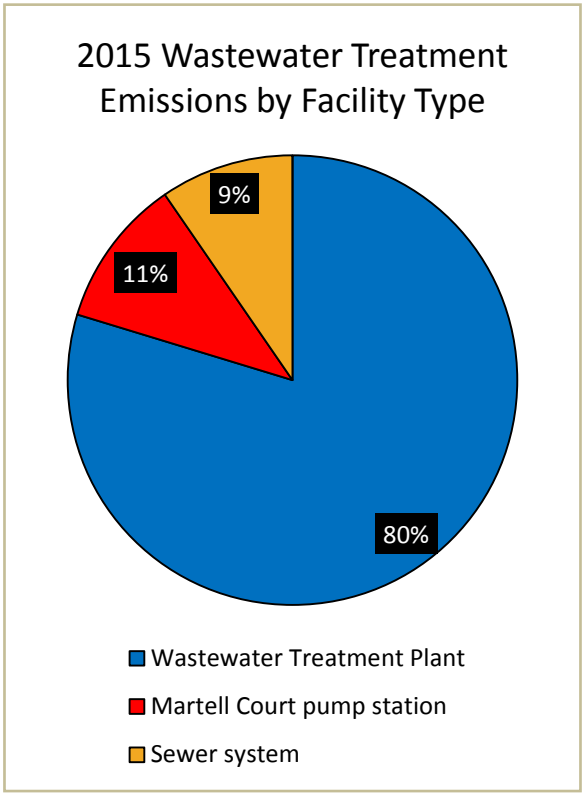


Figure 17: 2015 Municipal wastewater treatment emissions by facility type.

D. Water Delivery

Emissions from Water Delivery increased from 223 tons CO2e in 1995 to 276 tons CO2e in 2015, representing a 24% increase. This increase may be partially explained by variations in the proportion of water supplied using well water versus surface water. Access to well water requires more energy than surface water due to the energy required to operate well pumps. It is possible that a higher proportion of water was supplied using well water in 2015 in comparison to 1995, resulting in higher emissions in 2015.

Water Delivery Sector Definition

The Water Delivery Sector encompasses emissions from the Water Treatment Plant located at 555 Roxbury Road as well as emissions resulting from water supply and delivery (i.e. energy used to power the water delivery pumps).

In 2010, the City of Keene installed hydroelectric water turbines at the Water Treatment Plant (WTP). In 2015, 100% of the electricity used at the plant was offset by the power generated from the hydroelectric water turbines. Thus, the only emissions from the WTP in 2015 came from propane use to heat the building. Figure 18 provides the breakdown of emissions from the Water Supply Sector by energy source, and Figure 19 shows the emissions broken out by the type of facility. The WTP was responsible for 14% of the Water Delivery emissions in 2015. The remaining emissions resulted from electricity and a small amount of propane used to operate water distribution pumps.

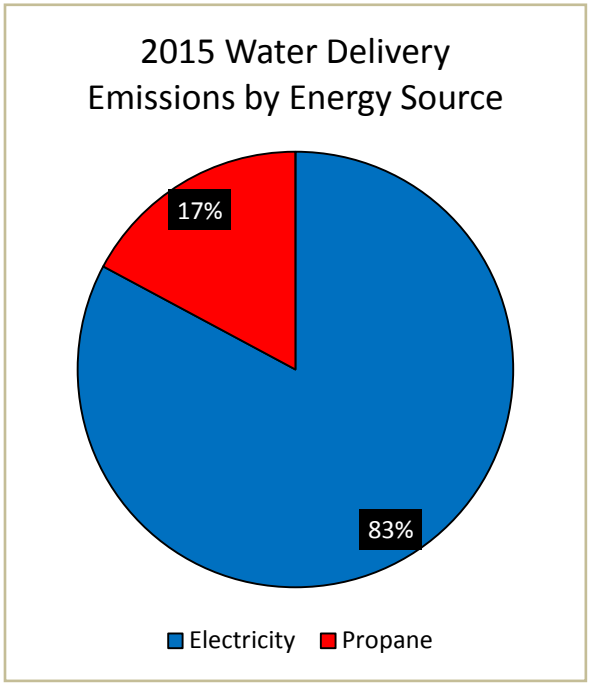


Figure 18: 2015 municipal water delivery emissions by energy source.

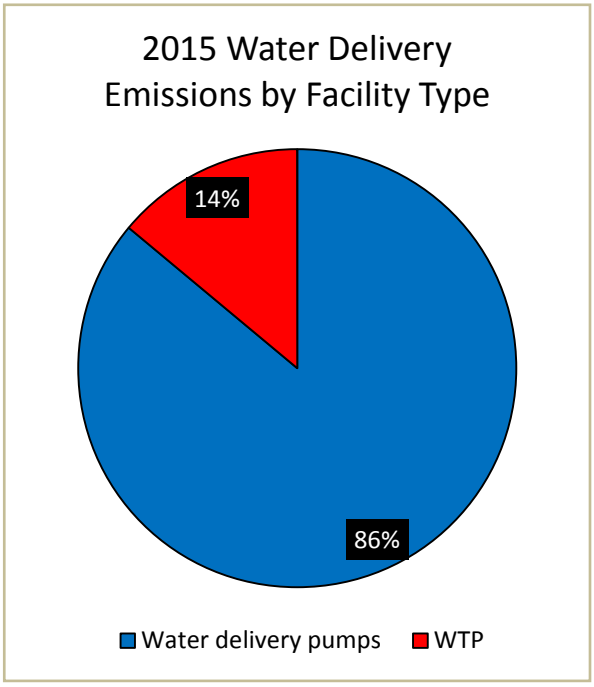


Figure 19: 2015 municipal water delivery emissions by facility type.

E. Streetlights & Traffic Signals

Emissions from streetlights and traffic signals decreased from 254 tons CO2e in 1995 to 158 tons CO2e in 2015, representing a 38% decrease. Figure 20 provides the breakdown in emissions for this sector by lighting type. The majority of emissions (87%) from this sector are associated with streetlight electricity use. The remaining emissions are split between park lighting (5%), other outdoor lighting (5%), and traffic signals (3%). Between 2000 and 2010, traffic signals, parking facility lights, and the lights on Main Street were converted to LEDs, ensuring their low contribution to emissions.

Streetlights and Traffic Signals Sector Definition

The Streetlights and Traffic Signals Sector includes indirect emissions associated with the purchase and use of electricity for traffic signals, streetlights, park lighting, and other outdoor lighting (such as holiday lighting).

The City of Keene is estimated to have 1,155 streetlights, most of which were high pressure sodium streetlights in 2015. In 2017, the City replaced the majority of these streetlights with LEDs, a measure that is expected to avoid about $1.5 million in energy costs over a 20-year period.

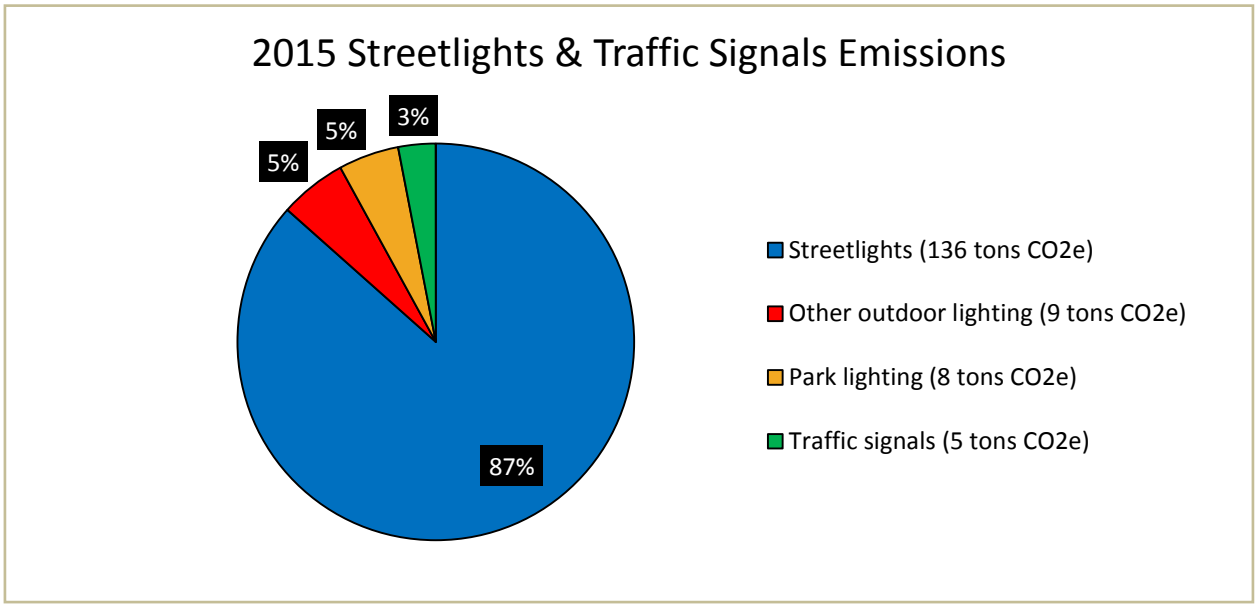


Figure 20: 2015 Streetlight and Traffic Signals Sector emissions for the City of Keene.

F. Airport Operations

Emissions from the Airport Operations Sector went from 211 tons CO2e in 1995 to 129 tons CO2e in 2015, representing a 39% decrease. Energy use went from 2,776 MMBTU in 1995 to 1,641 MMBTU in 2015, representing a 41% decrease. Figure 21 compares emissions from the Airport Operations sector by energy source for 1995 and 2015.

The reduction in energy use and emissions at the Keene Dillant-Hopkins Airport are attributable, in part, to upgrades that were made to a number of appliances to improve their efficiency, including the heating system and controls, building lighting, airfield lighting, obstruction lights, and hazard beacons.

Airport Operations Sector Definition

The Airport Operations Sector includes emissions from the operation and maintenance of the Keene Dillant-Hopkins Airport located at 80 Airport Road in Swanzey, NH. This includes emissions from airfield lighting, maintenance equipment, and the airport main building (including the restaurant). It does not include emissions from air traffic. Emissions from air travel are reported in Appendix A under the Transportation Sector of the Community Inventory.

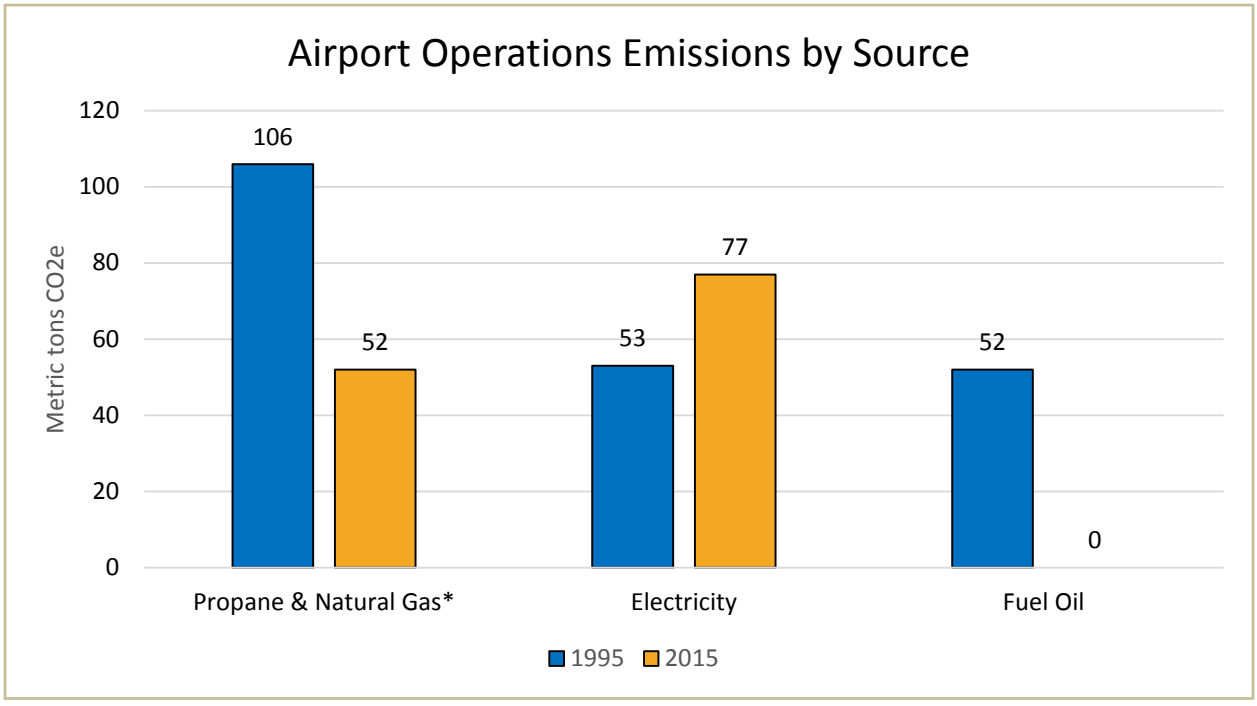


Figure 21: Airport Operations Sector emissions for the City of Keene by energy source in 1995 and 2015. *In 1995, the Airport Operations Sector used a combination of propane and natural gas, whereas in 2015 the sector used only propane.

4. MUNICIPAL SOLID WASTE

The City of Keene operates a municipal landfill which was capped and closed in 1999. While this landfill is no longer accepting waste, emissions from past generation of solid waste disposed in the landfill are still occurring today. The majority of emissions from this sector (99.9%) in 2015 were due to methane releases from the landfill, with the remaining 0.1% coming from energy used to heat and power the Keene Transfer Station and Recycling Center.

Municipal Solid Waste Sector Definition

Municipal solid waste emissions include emissions from energy use at the Keene Transfer Station and Recycling Center as well as fugitive methane emissions from the landfill operated by the municipality. This sector estimates inventory year emissions associated with waste disposal in previous years with a focus on waste disposed of within the community, regardless of where it was produced. Since there is insufficient data to calculate the municipal contribution to the total waste stream for the City of Keene, this is included within the community wide analysis of the inventory.

Between 1995 and 2015, solid waste emissions decreased from 205,064 tons CO2e to 8,820 tons CO2e, representing a 96% decrease. This reduction in emissions is partially due to the fact that the amount of organic material in the closed landfill available to undergo decay has decreased over time, resulting in fewer fugitive methane emissions. In addition, a partial LFG collection system was installed in 1994 to collect and combust LFG. A more comprehensive system with a total of 17 gas collection wells was installed in 1999 when the landfill was capped. These LFG capture systems are estimated to have avoided 569,898 tons CO2e in 1995 and 260,862 tons CO2e in 2015, or a combined total of 830,760 tons CO2e, as shown in Figure 22.

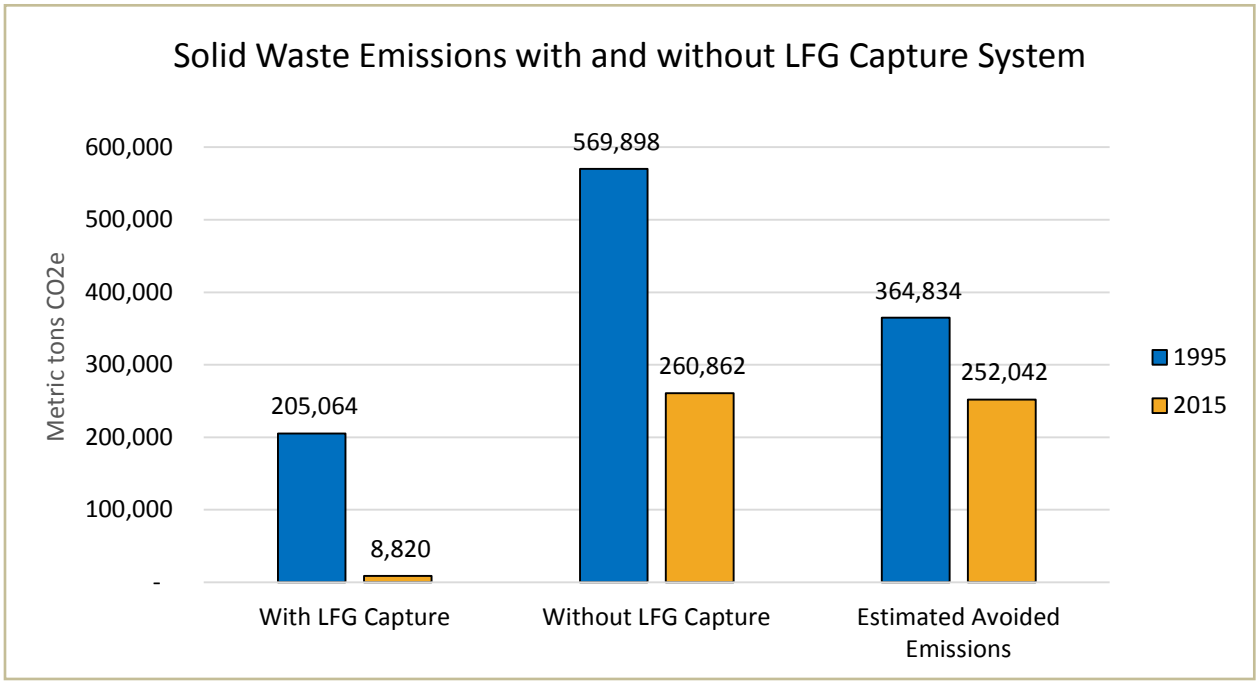


Figure 22: Municipal Solid Waste Sector emissions with and without LFG capture.

5. CONCLUSION

5.1 Community Emissions

Overall, emissions from the Keene community decreased by about 2.8% from 1995 to 2015, and per-capita emissions decreased by 5.4%. In 2000 it was predicted that emissions from the community would increase by 26% between 1995 and 2015 if no action was taken. Although the community did not reach the emissions reduction target of 10% below 1995 levels by 2015, the community was successful at reducing overall emissions while accommodating a modest 2.8% increase in population. The only sector within the Community Inventory that increased in emissions from 1995 and 2015 was the Residential Sector. All other sectors – Transportation, Commercial & Industrial, and Solid Waste – achieved a reduction in emissions over this timeframe.

Factors that contributed to an overall reduction in emissions for the Community Inventory include an increase in the overall fleet fuel economy, fewer heating degree days in 2015 compared to 1995, fuel switching from fuel oil to propane, a cleaner electricity supply, increases in energy efficiency among the Commercial and Industrial Sector, and a reduction in waste generation coupled with an increase in residential and commercial recycling and composting.

Next steps should include setting an updated emissions reduction target for community-wide emissions and identifying opportunities and strategies to achieve further emissions reductions.

5.2 Municipal Emissions

The results of the Municipal Inventory for the City of Keene show that the City exceeded its goal of reducing municipal government emissions to 20% below 1995 levels by 2015. The City of Keene has implemented a variety of energy efficiency and cost savings measures over the past 20 years, which has resulted in a 25% decrease in emissions. In addition, the installation of a landfill gas collection system at the Keene Municipal Landfill is estimated to have avoided about 830,760 tons CO2e in 1995 and 2015 and contributed to a 96% decrease in emissions from the landfill. These results indicate that the City's efforts to reduce energy use and save costs have been an overwhelming success.

Moving forward, the City should continue to pursue measures to increase energy efficiency, energy conservation, and reliance on renewable energy sources. In addition, the City should set an updated emissions reduction target and continue tracking emissions to evaluate progress.