## City of Keene, New Hampshire

# Greenhouse Gas Emissions Inventory

## 2006 – 2008

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## 1. Executive Summary

Climate change represents one of the greatest challenges facing New England communities over the coming decades. Changing growing seasons, fewer snow cover days, extreme weather events and flooding, and rising energy costs are only a few impacts that the region is already experiencing. The people and government of Keene now share the opportunity and responsibility to meet these challenges and improve quality of life through measures such as increasing energy efficiency, controlling energy costs, and reducing greenhouse gas emissions.

In 2000, the City of Keene signed on to the Cities for Climate Protection Campaign, a program administered by the International Council for Local Environmental Initiatives (ICLEI). This program calls for participating members to develop and implement climate action plans that set clear targets for reducing emissions. The Cities for Climate Protection Committee developed Keene's Climate Action Plan, which was formally adopted by City Council in February of 2004. This action plan set two emissions reduction goals, one for community wide emissions and one for municipal emissions. The first target, which includes residential, commercial/industrial, transportation, and government sectors, calls for a 10% reduction in emissions below 1995 levels by 2015. The second target for municipal emissions is more ambitious, aiming for a 20% reduction in emissions below 1995 levels by 2015.

The baseline greenhouse gas emissions inventory was completed in 2000 using data from 1995. The final greenhouse gas inventory will compare the baseline year data to 2015 emissions data to verify the results of emissions reduction measures. This 2006-2008 greenhouse gas inventory is an interim report, compiled to track patterns in greenhouse gas emissions and show progress towards the City's emission reduction goals.

The first part of this report is a community wide analysis based on public data, which provides estimates of energy use and greenhouse gas emissions within the political boundary of Keene. The second half of the report focuses on a government analysis, giving an in-depth look at the energy use and emissions profile of the City of Keene's municipal operations. The report ends with possible next steps and conclusions. The detailed methodology, glossary of terms, and other supporting documents can be found in the Appendices.

## 2. Methodology

Two analyses are included in this report. The first analysis used publicly available community wide data to profile Keene's energy use. The second analysis used data from the operations of Keene's government to profile municipal operations in much greater detail. The municipal analysis classifies emissions according to their Scope (1, 2, or 3); for a full explanation of the Scopes classification system see Appendix B-3. The framework used to evaluate and report emissions comes from the Local Government Operations Protocol version one (LGOP),[1] and energy use information was translated into emissions information using ICLEI-USA's Clean Air and Climate Protection Software (CACP)[2]. Appendix B describes the methodology used for this inventory in greater detail.

### Explanation of Output Units

The output units for the CACP software are carbon dioxide equivalents, or $CO_2e$. Carbon dioxide equivalent data come from global warming potential values (GWP), which are calculated based on three experimentally determined factors for a given greenhouse gas species: 1) the absorption of infrared radiation, 2) the spectral location of its absorbing wavelengths, and 3) its atmospheric lifetime. GWP translates the effect of each greenhouse gas into the quantity of $CO_2$ required to produce the same effect. For example, over 100 years one ton of methane has the same effect as 21 tons of $CO_2$; therefore the GWP of methane is 21 and 1 ton of methane is translated into 21 tons $CO_2e$.

This inventory assesses emissions of all six internationally-recognized greenhouse gases regulated under the Kyoto Protocol, which includes carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride ($SF_6$). Global warming potential values come from the LGOP; a table of global warming potentials for these gasses can be found in Appendix D. Figure 1, below, shows the global warming potentials for the three common greenhouse gasses assessed in this report.

### Limitations

The CACP 2009 software depends upon numerous assumptions, and it is limited by the quantity and quality of available data. In instances where data sets were incomplete, extrapolation or interpolation methods were used to provide best estimates for missing data. Certain scope three emissions, such as emissions from transporting solid waste and air traffic associated with the Keene Airport, were outside the scope of this report. Other data sets, such as heating fuel use in the residential sector, are calculated based on estimates rather than measured data. With this in mind, it is useful to think of any specific number generated by the model as an approximation of reality, rather than an exact value.

[1] Local Government Operations Protocol, version 1. http://www.arb.ca.gov/cc/protocols/localgov/archive/final_lgo_protocol_2008-09-25.pdf

[2] Clean Air and Climate Protection 2009 Software, version 2.1, June 2009. Tables release date: 2009 -06-05.

## 3. Community wide Inventory Results

### 3.1 Overview of community wide energy use and emissions

By 2008, Keene's community wide emissions had increased from 362,619 tons $CO_2e$ in 1995 to 424,965 tons of $CO_2e$, a 17% increase[3]. This data suggests that, as of 2008, the Keene community was not on track to achieve its goal of reducing emissions to 10% below 1995 levels by 2015. Figure 3.1 shows the general trend in emissions from 1995-2008 along with the 2015 emissions reduction target of 326,324 tons $CO_2e$.

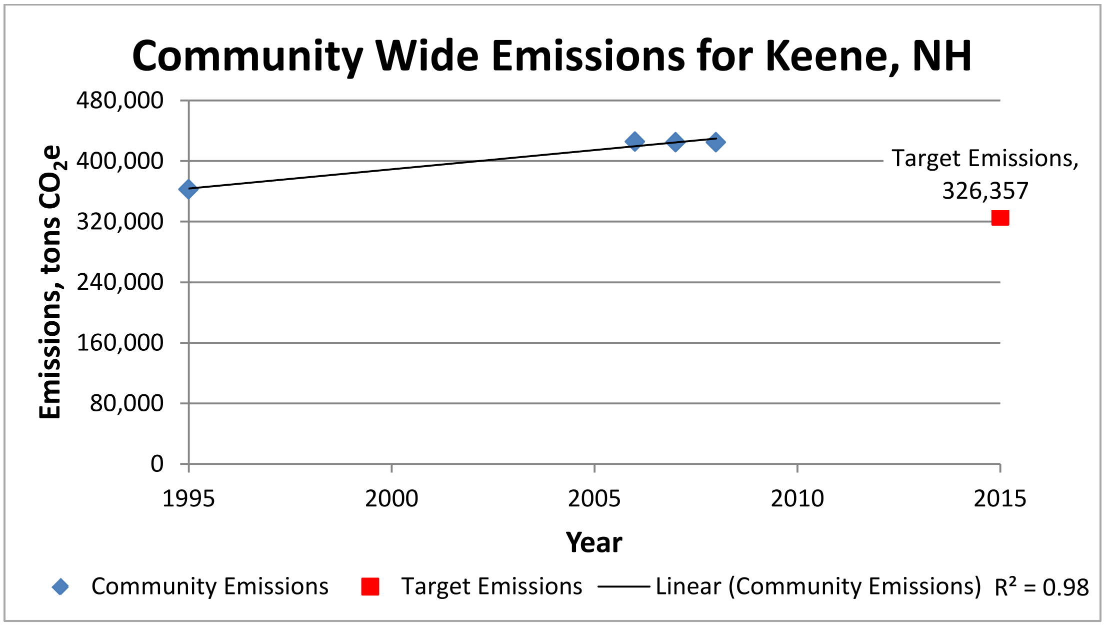


**Figure 1. Total community wide emissions with 2015 target emissions level shown in red.**

| Emissions by Sector (tons $CO_2e$) | 1995 | 2008 | Change | Percent Change |
|---|---|---|---|---|
| Transportation | 220,027 | 205,102 | -14,925 | -7% |
| Commercial/Industrial | 68,810 | 113,654 | 44,844 | 65% |
| Residential | 67,281 | 89,238 | 21,957 | 33% |
| Municipal | 6,464 | 6,399 | -65 | -1% |
| Solid Waste | 37 | 10,572 | 10,535 | **28472% |
| **Total** | **362,619** | **424,965** | **62,346** | **17%** |

**Table 1. Community wide emissions by sector for 1995 and 2008. **This value is explained in the solid waste sector below.**

[3] Keene's 1995 base year greenhouse gas inventory was revised using current methods to allow comparison of data. See Appendix B-2 for explanation of revisions.

| Energy Use by Sector (MMBtu) | 1995 | 2008 | Change | Percent Change |
|---|---|---|---|---|
| Transportation | 2,719,072 | 2,565,003 | -154,069 | -5.7% |
| Commercial/Industrial | 783,274 | 989,299 | 206,025 | 26.3% |
| Residential | 791,615 | 1,031,328 | 239,713 | 30.3% |
| Government | 64,413 | 61,225 | -3,188 | -4.9% |
| **Total** | **4,358,374** | **4,646,855** | **288,481** | **6.6%** |

**Table 2. Community wide energy use, change in energy use, and percent change by sector for 1995 and 2008. An MMBtu is equal to 1 million BTU (British Thermal Units).**

## 3.2 Breakdown by Sector

Keene's community emissions profile departs from the nearly even division of emissions between the residential, commercial/industrial, and transportation sectors common in cities of comparable populations. Keene's status as a regional commercial and educational hub and as a waypoint along four regionally significant highways greatly increases the share of local emissions due to transportation uses.

While the transportation sector shrank in both absolute and proportional emissions from 1995 to 2008, it is still by far the largest source of emissions in Keene at 48.3% of total emissions. The commercial sector increased emissions over the 1995 level by 65% in 2008, mostly due to new commercial development that occurred after 1995. Residential sector emissions increased by 33% from 1995 to 2008, and municipal sector emissions decreased by 1% from 1995 to 2008. Solid waste emissions increased, largely due to the closure of Keene's landfill; however they are a small percentage of the total (2.5%). Figure 3 shows the division of energy use and resulting emissions among the transportation, commercial, residential, and government sectors and solid waste for 2008. Figure 4 shows the change in emissions by sector from 1995 to 2008.

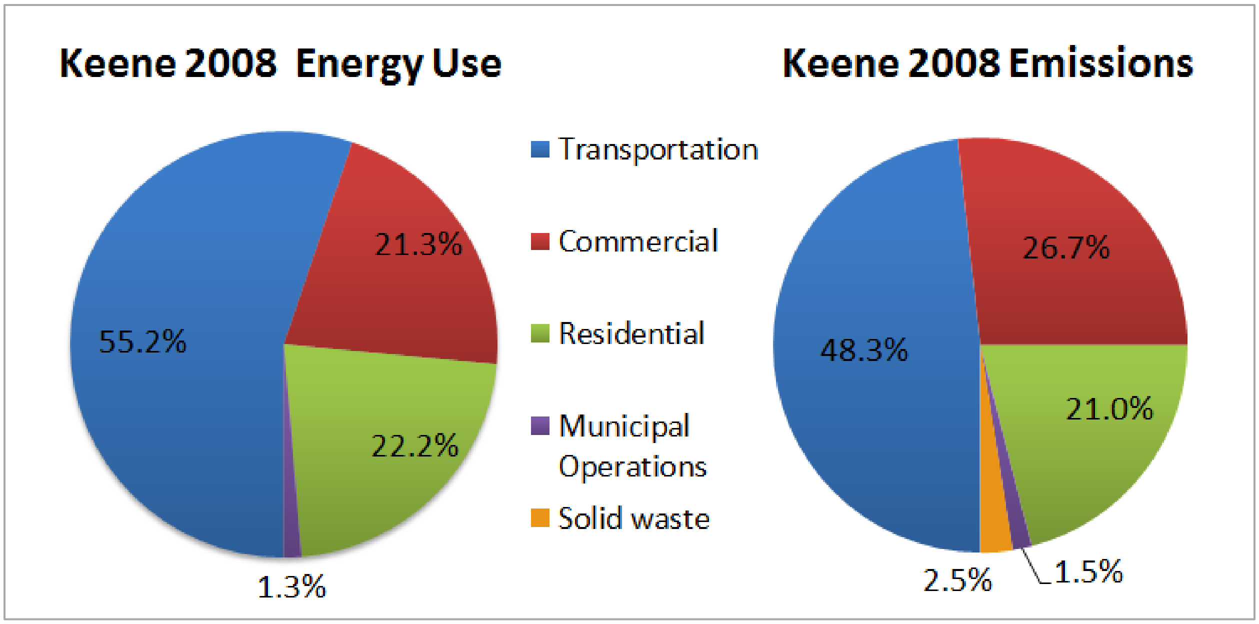


**Figure 2. Division of energy use and resulting emissions among the main sectors of Keene, NH.**

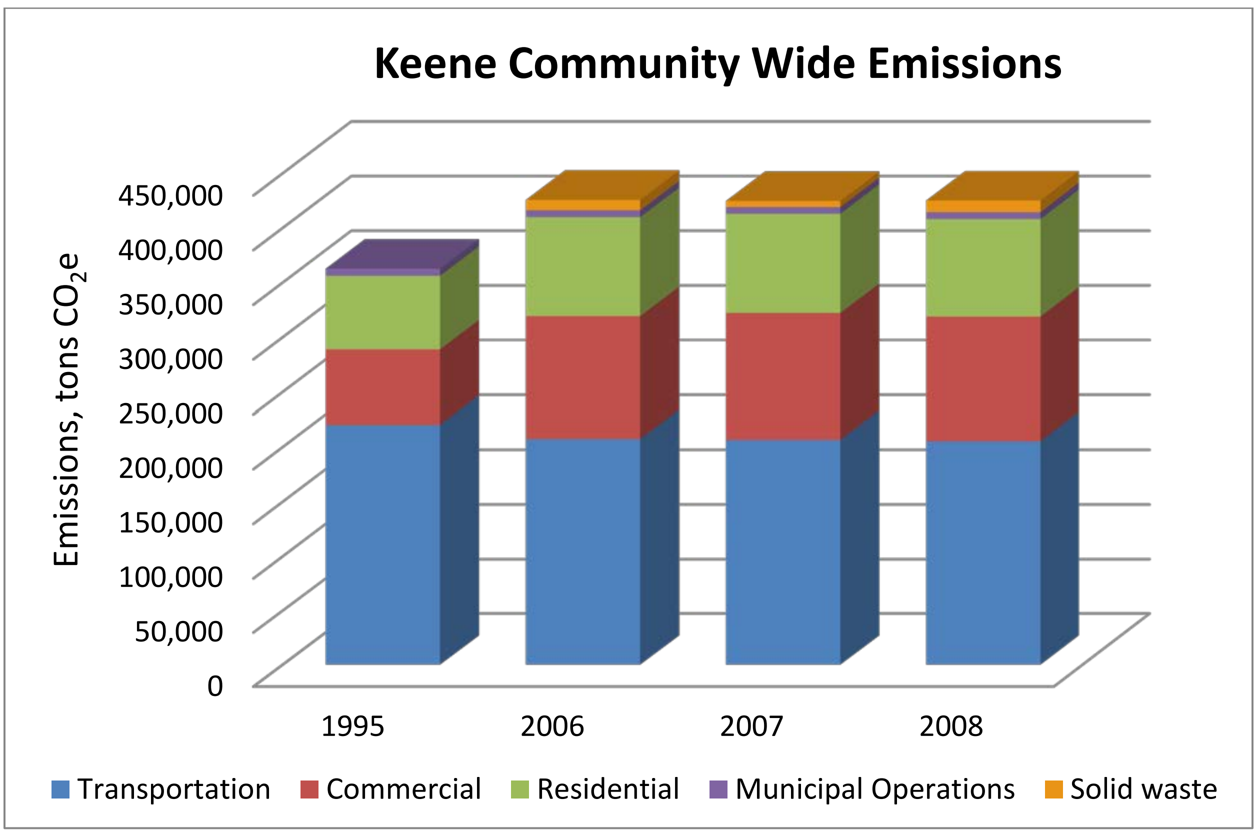


**Figure 3. Emissions for the City of Keene by sector, expressed in $CO_2e$ for 1995 and 2006-2008.**

### 3.2.1 Transportation

Keene's 2008 transportation emissions were 205,102 tons $CO_2e$, 48.3% of Keene's overall emissions and 58.6% of Keene's energy use. In comparison, the state of New Hampshire attributed only 36% of its energy consumption to transportation in 2010.[4] Keene's relatively high transportation emissions result from Keene's position along regional transportation routes as well as transportation patterns that favor commuting by personal motor vehicles. According to data from the US Census Bureau, 48% of the people working in Keene in 2008 commuted from more than 10 miles away.[5] Other transportation uses that contribute to emissions include people driving in from surrounding areas for shopping, services or other non-work trip reasons, passing through on the way to another destination, and commuting from Keene to another destination for work. Emissions from the operation of the Keene airport are included under the government sector.

### 3.2.2 Commercial and Industrial

By 2008, the commercial and industrial sector had increased emissions from 68,810 tons $CO_2e$ in 1995 to 113,654 tons $CO_2e$, a 65% increase. Energy use went from 783,274 MMBtu to 989,299 MMBtu, a 26.3% increase. This trend can be partially explained by new commercial development that occurred between 1995 and 2008, including the addition of the Monadnock Marketplace.

The energy mix in this sector is dominated by electricity, with share averaging around 60% of sector use over time since 1995. Fuel oil use averages around 30%. The remainder includes propane air and stored gasses. While propane air usage is measured, estimates of stored gas usage are particularly rough due to lack of public information on commercial/industrial uses, which may include major energy-tied uses such as building heat, heat-based processes, and electricity and pressure generation.

### 3.2.3 Residential

In 2008, Keene's residential sector produced 89,238 tons $CO_2e$, a 33% increase over the 1995 level of 67,281 tons $CO_2e$. Residential energy use and emissions were dominated by heating fuel oil at 66% and 62% of the total, respectively. Electricity use was the next most significant energy and emissions source. After electricity, far lesser usage of wood, utility propane air, stored gasses (including propane and natural gas), and coal account for the remainder of residential energy use and emissions. The CACP 2009 analysis software considers wood to be a carbon-neutral resource.

[4] US EIA. http://www.eia.gov/state/?sid=NH
[5] Data taken from 2008 Longitudinal Employer-Household Dynamics data report.

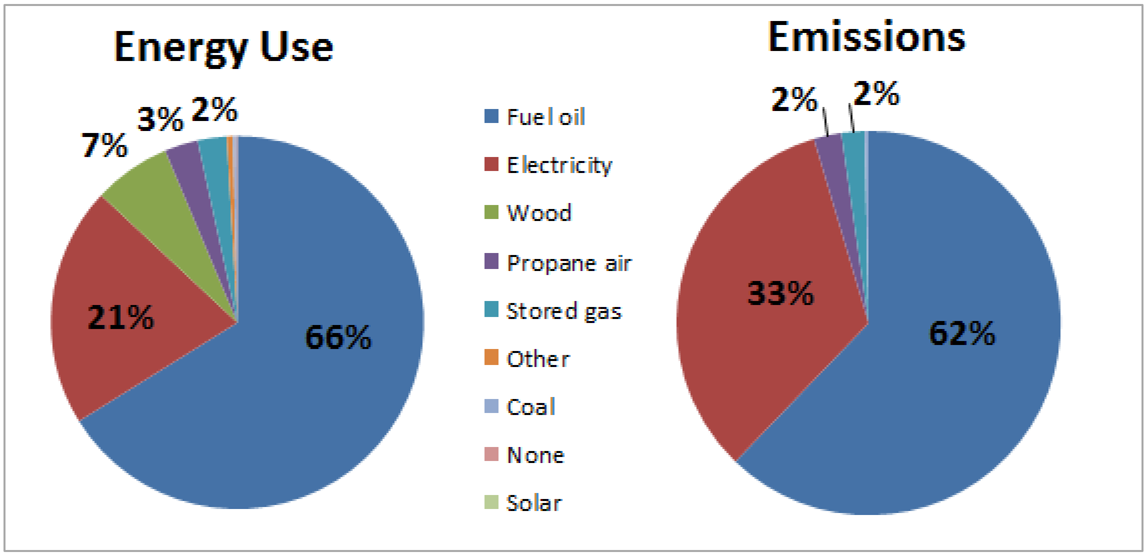


**Figure 4. 2008 proportional energy use and resulting emissions for the residential sector.**

### 3.2.4 Municipal Facilities and Operations

The municipal sector represents the total emissions output of Keene's city government as a portion of the community wide inventory. The municipality's emissions of 6,399 tons $CO_2e$ constituted 1.5% of community wide emissions in 2008. Municipal energy use and emissions are analyzed in detail within the municipal facilities and operations analysis, on page 11 of this report.

### 3.2.5 Solid Waste

Emissions from solid waste processing increased drastically from 1995 to 2008, going from 37 to 10,572 tons $CO_2e$. This large jump in emissions is due to changes in Keene's solid waste processing methods. In 1995, Keene's landfill was still operating and most waste was landfilled. The CACP 2009 analysis software considers landfilling to be a method of storing carbon, also called sequestration. By 2006, Keene's landfill had been closed and the non-recycled waste stream was divided between the Turnkey Landfill in Rochester and the Wheelabrator Incinerator in Claremont.[6] Incineration is considered a source of emissions. Therefore, the switch from using the landfill to the incinerator is responsible for the large jump in emissions related to solid waste processing. See Appendix B-2 for a detailed explanation of emissions and sequestration of carbon due to solid waste processing.

Within the community-wide analysis, the solid waste sector accounts for emissions from solid waste processing. Emissions from the operation of solid waste facilities are included in the government analysis.

[6] The Wheelabrator incinerator closed in 2013; all waste is now sent to the Turnkey Landfill in Rochester, NH.

# 4. Municipal Facilities and Operations Inventory Results

## 4.1 Overview of Municipal Results

By 2008, the Municipal Facilities and Operations sector (Municipal sector) emissions had decreased from 6,464 tons $CO_2e$ in 1995 to 6,399 tons of $CO_2e$, a 1 % decrease, and energy use went from 64,413 MMBtu to 61,225 MMBtu, a 4.9% decrease. While the general trend for energy use and emissions is decreasing slightly, according to the 2008 data the City is still not on track to reach its goal of a 20% reduction in emissions below the 1995 levels by 2015. Figure 5, below, shows the general trend in emissions from 1995-2008 as well as the emissions reduction target goal for 2015. Tables 3 and 4 show the total energy use and emissions for the City of Keene municipal operations.

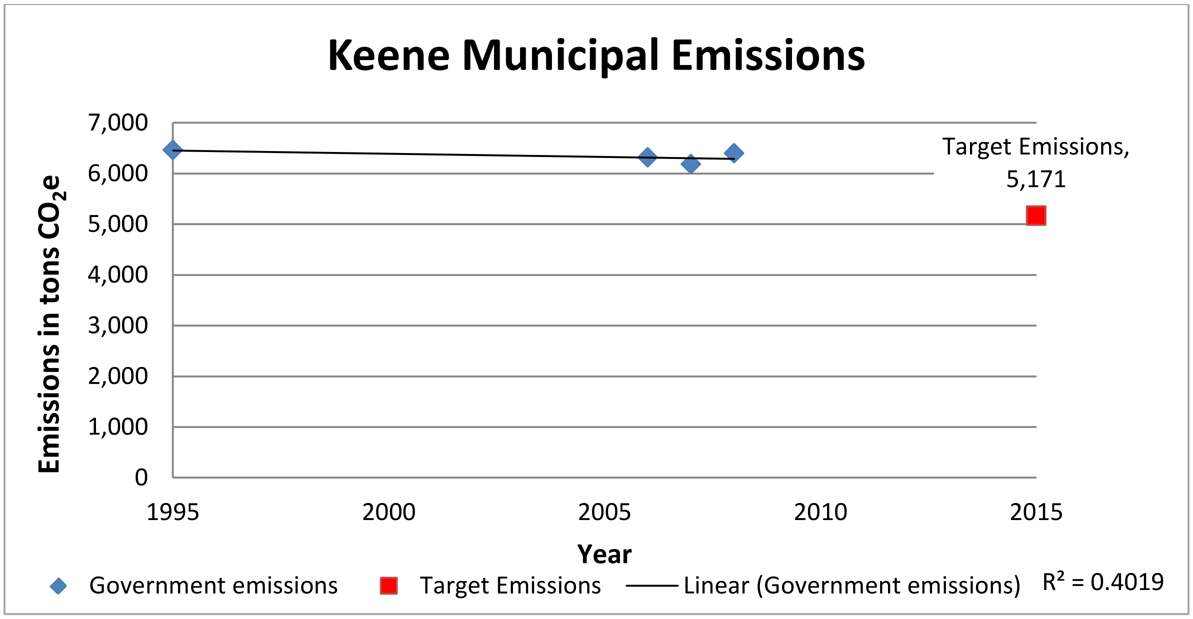


**Figure 5. Total municipal emissions from 1995-2008 with 2015 reduction target shown in red.**

| Municipal Emissions (tons $CO_2e$) | 1995 | 2008 | Change | Percent Change |
|---|---|---|---|---|
| Buildings, Parks & Rec | 2,578 | 2,568 | -10 | -0.4% |
| Vehicle Fleet | 1,280 | 1,135 | -145 | -11.3% |
| Wastewater Facilities | 1,644 | 1,637 | -7 | -0.4% |
| Solid Waste Operations | 274 | 2 | -272 | -99.3% |
| Airport | 211 | 128 | -83 | -39.3% |
| Streetlights & Traffic Signals | 254 | 426 | 172 | 67.7% |
| Water Supply Facilities | 223 | 503 | 280 | 125.6% |
| **Total** | **6,464** | **6,399** | **-65** | **-1.0%** |

**Table 3. City of Keene Municipal energy use, change in energy use, and percent change from 1995 to 2008, by sector.**

| Municipal Energy Use (MMBtu) | 1995 | 2008 | Change | Percent Change |
|---|---|---|---|---|
| Buildings, Parks & Rec | 29,785 | 26,237 | -3,548 | -11.9% |
| Vehicle Fleet | 14,774 | 13,176 | -1,598 | -10.8% |
| Wastewater Facilities | 10,074 | 10,691 | 617 | 6.1% |
| Solid Waste Operations | 3,405 | 2,259 | -1,146 | -33.7% |
| Airport | 2,776 | 1,332 | -1,444 | -52.0% |
| Streetlights & Traffic Signals | 1,917 | 3,109 | 1,192 | 62.2% |
| Water Supply Facilities | 1,682 | 4,421 | 2,739 | 162.8% |
| **Total** | **64,413** | **61,225** | **-3,188** | **-4.9%** |

**Table 4. City of Keene Municipal emissions, change in emissions, and percent change from 1995 to 2008, by sector.**

## 4.2 Breakdown by Sector

The municipal inventory is split into seven sectors: Buildings, Vehicle Fleet, Wastewater Facilities, Solid Waste Operations, Airport, Streetlights & Traffic Signals, and Water Supply Facilities. Figure 6 shows the division of energy use and resulting emissions among the sectors, and Figure 7 shows the change in emissions by sector from 1995 to 2008.

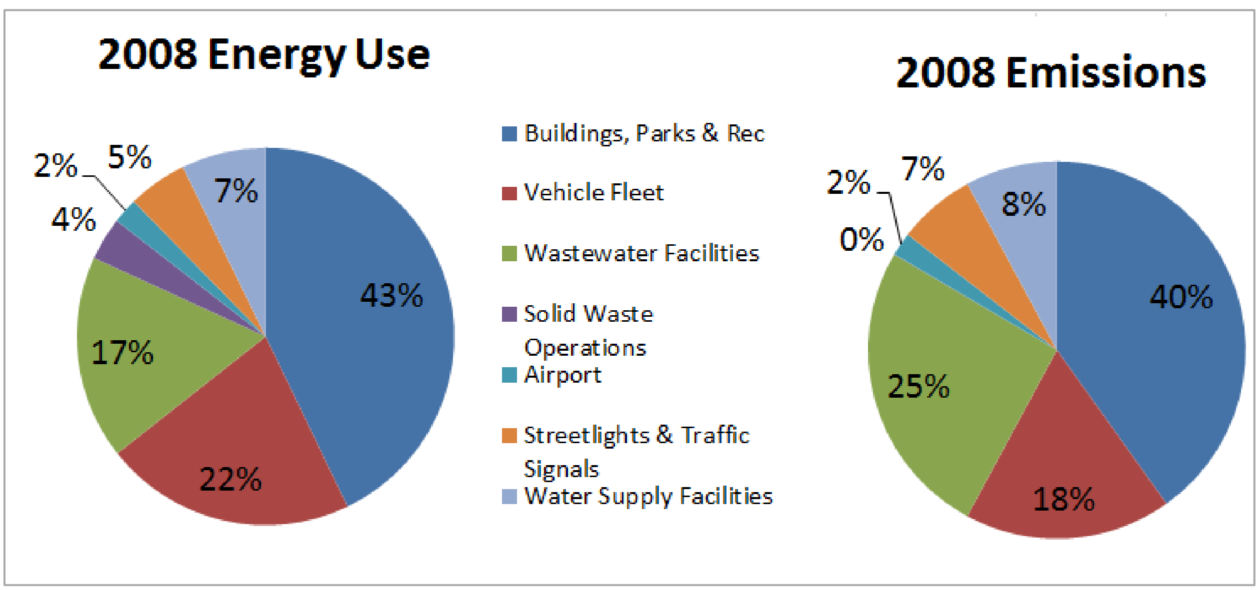


**Figure 6. Division of energy use and resulting emissions in 2008 among the main sectors of the Keene municipal government.**

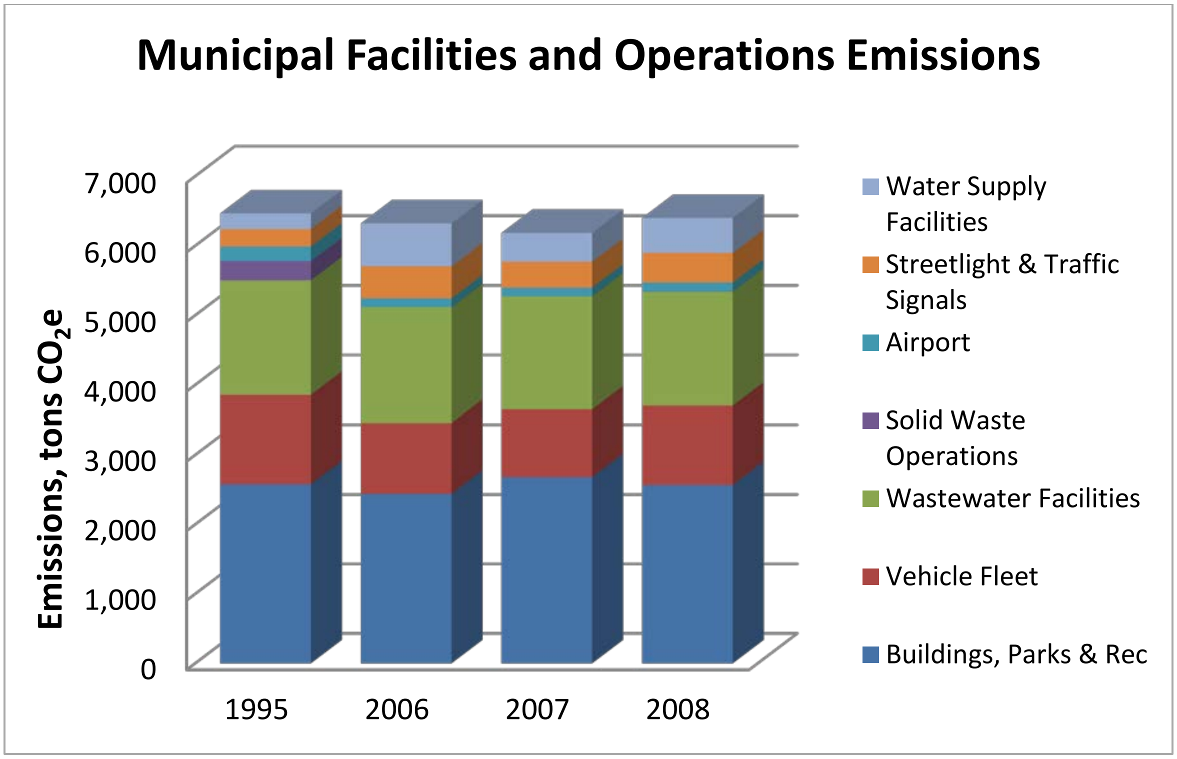


**Figure 7. City of Keene municipal emissions by sector for 1995 and 2006-2008.**

### 4.2.1 Buildings

The Buildings sector dominates the municipal government emissions profile, accounting for 40.1% (2,568 tons $CO_2e$) of total municipal emissions in 2008. Despite the addition of new buildings such as the City Garage, Police and Corrections building complex, this sector's energy use and emissions have stayed relatively constant compared to 1995 levels due to energy efficiency measures implemented in new buildings.

In 2008, the City Garage, Police and Corrections building complex at 350-400 Marlboro Street was responsible for 42.8% of the emissions output of the entire Buildings sector, or 17.2% of total municipal emissions. Sixty four percent of the City Garage, Police and Corrections building's 2008 emissions were produced from heating fuel. City Hall produced the next largest quantity of $CO_2e$ at 310 tons, or 12.1% of sector emissions. The majority (79.4%) of City Hall emissions resulted from electricity use, with the remainder from heating oil. Figure 8, below, shows building sector emissions by building as a percentage of the whole.

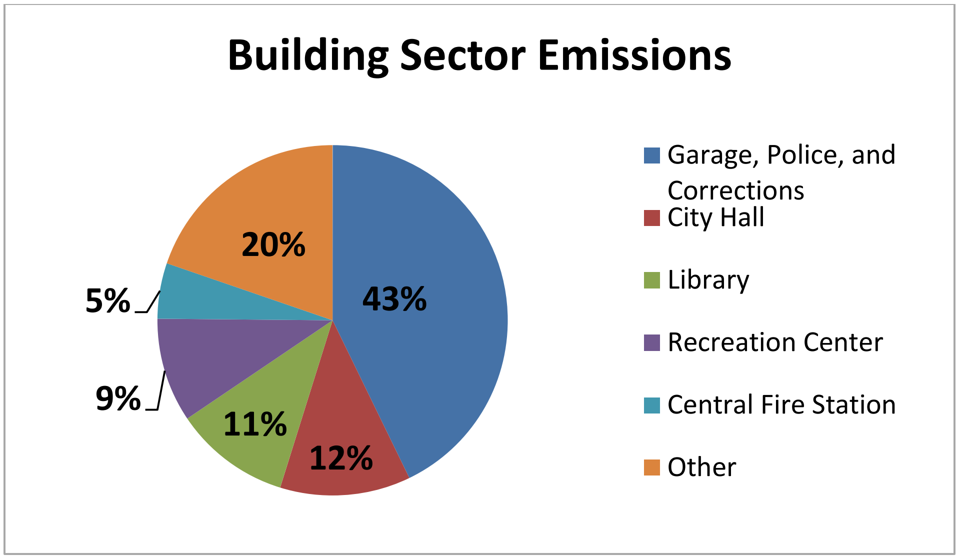


**Figure 8. Division of emissions among the City of Keene municipal building sector.**

### 4.2.2 Vehicle Fleet

The City of Keene's municipal vehicle fleet produced 1,135 tons of $CO_2e$ during 2008, or 17.7% of the municipal total. This is a reduction from the 1995 level of 1,280 tons $CO_2e$, but it is also a significant increase from the 2006 and 2007 levels of 968 and 1,135 tons $CO_2e$. Yearly variation in fleet emissions is partially dependent on weather events, construction and repair projects, and community traffic. The reduction in emissions from 1995 levels can be partially attributed to the use of B20 biodiesel fuel during the warmer months since 2002.

### 4.2.3 Wastewater Facilities

Wastewater treatment was responsible for 1,637 tons $CO_2e$ emissions in 2008, which was 25.6% of total municipal emissions. This is a slight reduction compared to 1995 levels, but yearly variability exceeds the difference between the two levels. Wastewater treatment emissions depend primarily on the amount of wastewater entering the sewer system, and are therefore seasonally variable with community water usage and weather.

In 2008, the wastewater treatment plant alone produced 87.1% of sector emissions, or 1,426 tons $CO_2e$. Of these emissions, 56.0% were due to electricity usage and 18.9% were from nitrous oxide ($N_2O$) emissions from the wastewater treatment process. The pumping station at Martel Court produced 11.9% of sector emissions via electricity use. The remaining 0.9% of sector emissions was generated through operation of the sewer system. To an extent, wastewater treatment emissions correlate with water delivery emissions. Efficiency improvements in pumping and processing typically result in a lower ratio of emissions to wastewater processed.

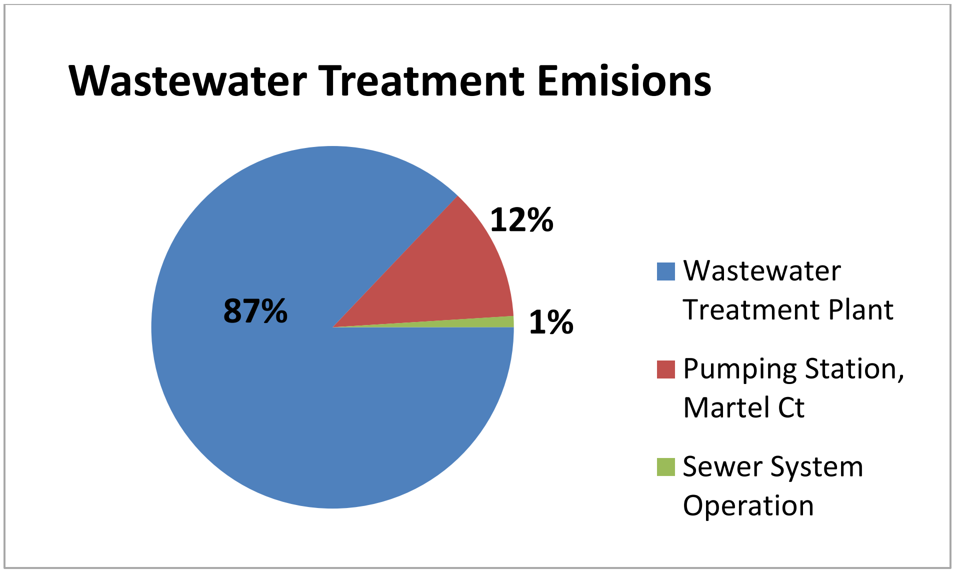


**Figure 9. Division of emissions among wastewater treatment facilities and operations in 2008.**

### 4.2.4 Solid Waste Operations

Within the municipal analysis, the solid waste sector refers to emissions generated by the operation of Keene's solid waste facilities. It specifically excludes the waste stream, which is already included in the community analysis. The emissions from the City of Keene's solid waste operations account for less than 1% (2 tons) of municipal $CO_2e$ emissions. The City's solid waste operations produce few emissions relative to the size of the operation because the recycling center and transfer station are powered primarily by landfill gas (methane) from the combined heat and power plant. This methane-powered generation system is estimated to be 75% efficient, typical for its class.

### 4.2.5 Airport Operations and Maintenance

The Keene Airport accounted for 128 tons $CO_2e$ emissions, or 2% of total municipal emissions. This is almost a 40% decrease from 1995 levels, which is due to upgrades that were made to a number of appliances to improve their efficiency. Upgraded appliances include the heating system and controls, building lighting, airfield lighting, obstruction lights, and hazard beacons. The airport sector does not include emissions from air traffic, which are Scope 3 emissions.[7]

### 4.2.6 Streetlights and Traffic Signals

Streetlights and traffic signals account for 426 tons $CO_2e$ in 2008, or 6.7% of total municipal emissions. This is an increase of 67.7% over 1995 levels, which may be due in part to new street lights that have been installed since 1995. Street lighting dominates the usage in this sector at 96.5% of sector emissions. Traffic signals have been converted

[7] See Appendix B-3, (p. 31) for a description of Scope 3 emissions.

to LED fixtures, which ensure their low contribution to emissions. Emissions from streetlights were calculated as a function of the amount of electricity required for operation.

### 4.2.7 Water Supply Facilities

Water treatment and delivery accounted for 503 tons $CO_2e$ emissions in 2008, or 7.9% of total municipal emissions. This is an increase of 125.6% from the 1995 levels of 223 tons $CO_2e$. This increase can be explained by the higher proportion of water that was supplied using well water during 2008 versus 1995 due to surface water quality concerns. Well water requires more energy than surface water because of the energy required to operate well pumps. Efficiency improvements in pumping and processing typically result in a lower ratio of emissions to water delivered.

Figure 10, below, shows the division of emissions between the water treatment facility and water supply and delivery operations. Water supply and delivery were responsible for 66.1% (333 tons $CO_2e$) of emissions, primarily through electricity used for pumping well water.

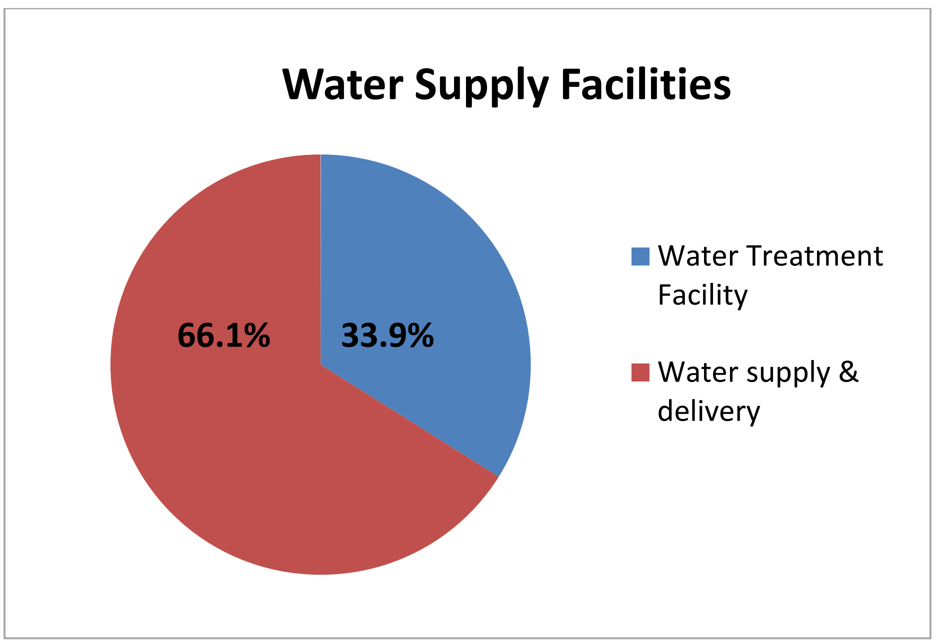


**Figure 10. Division of emissions among water supply facilities for 2008.**

# 5. Discussion and Next Steps

## 5.1 Trends and Forecast

### Community Results

The results of the community wide analysis show that energy use and emissions are increasing. This represents a challenge for meeting the community greenhouse gas reduction goal of reducing emissions to 10% below 1995 levels by 2015. Emissions increased by 17% from 1995 to 2008, however in order to achieve the greenhouse gas reduction goal, Keene will need to reduce emissions 23% below 2008 levels. Figure 11, below, shows the forecast of emissions based on a business as usual scenario for Keene along with the emissions levels needed to achieve the reduction goal. In the business as usual forecast, it is assumed that no further greenhouse gas reduction measures will be implemented and that each sector of the community will experience similar growth rates as in the past. Figure 12 shows the forecasted emissions for each sector of the community.

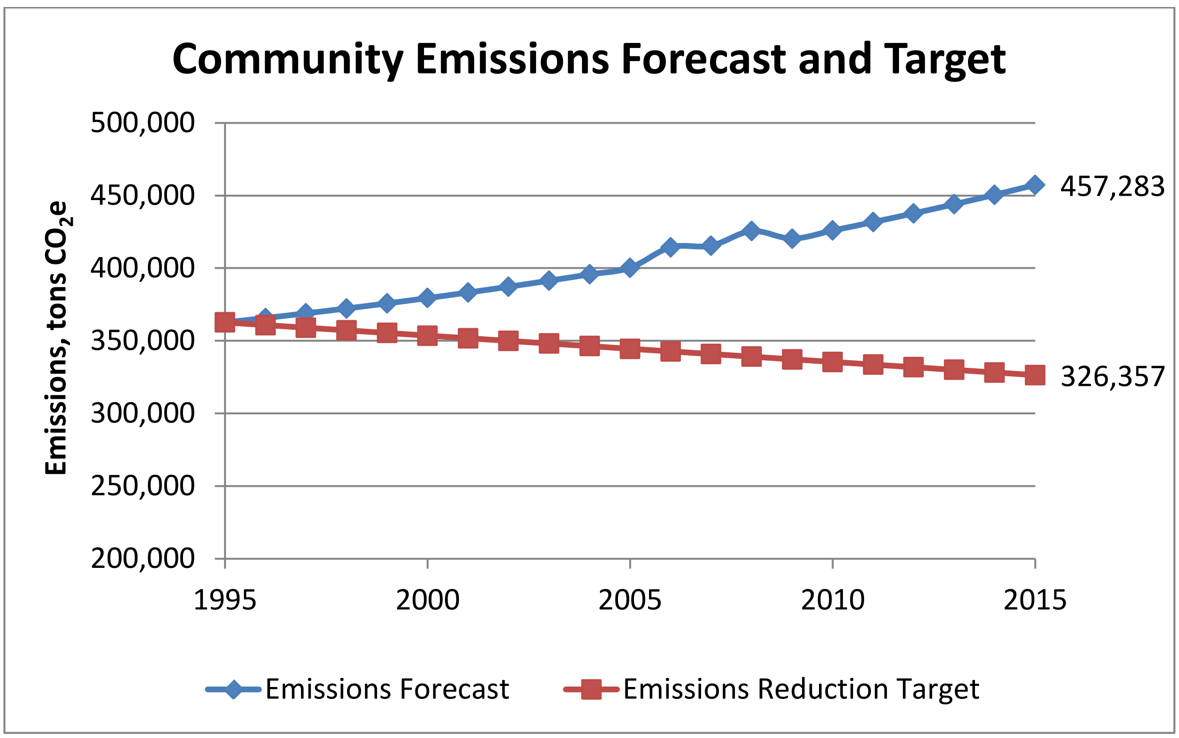


**Figure 11. City of Keene community wide emissions forecast and emissions reduction target.**

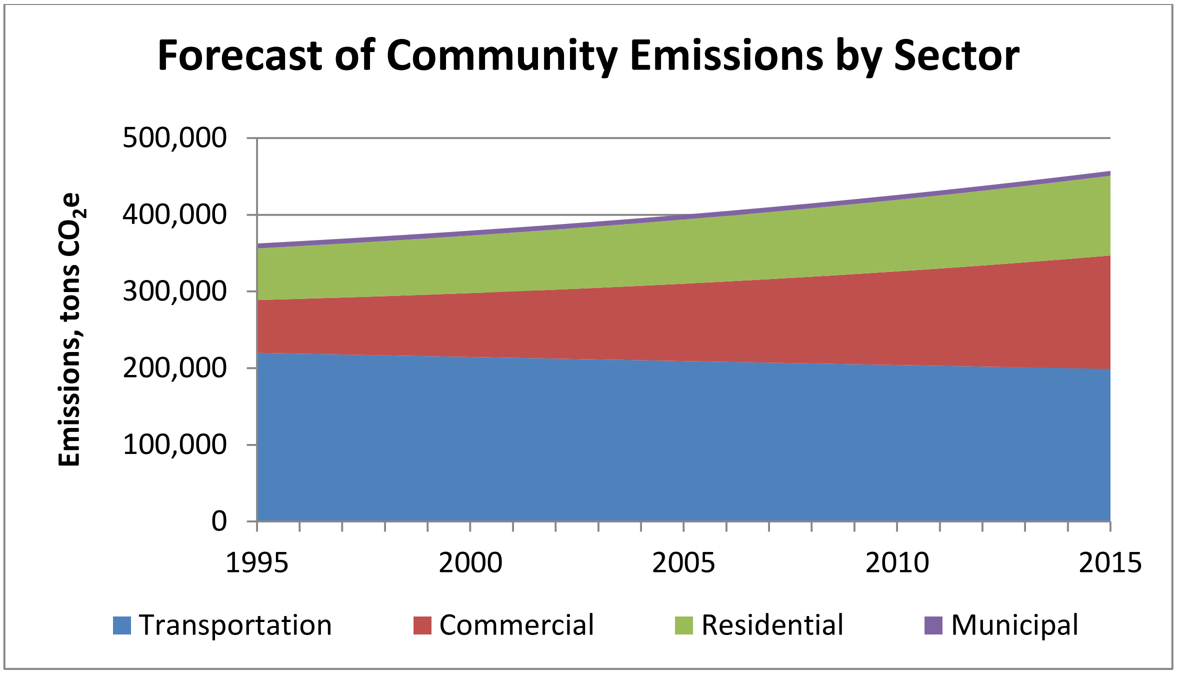


**Figure 12. City of Keene forecast of community emissions by sector. The solid waste sector was not included in the forecast due to uncertainty in future growth rates.**

It is interesting to note that during the time period from 1995-2008, population levels stayed relatively constant in Keene even as emissions went up. As a result, per capital GHG emissions for Keene have increased from 16.14 tons $CO_2e$ per person in 1995 to 18.76 tons $CO_2e$ per person in 2008, a 16% increase. Per capita emissions under a business as usual scenario are expected to be about 18.73 tons CO2e per person in 2015.

## Municipal Results

Unlike the community wide analysis, the municipal facilities and operations analysis shows that emissions have stayed relatively constant from 1995-2008. During these years, the municipal government implemented various greenhouse gas reductions measures. For example, in 2003 the City of Keene started using biodiesel blends in the municipal fleet. This measure alone is estimated to reduce emissions from the fleet by approximately 417 tons $CO_2e$ per year. In addition to using biodiesel, the city also installed a landfill gas-to-energy generator at the Keene landfill with an estimated savings of 140 tons $CO_2$ per year, and switched its traffic lights to LED technology with an estimated savings of 15 tons $CO_2$ per year.

Under a business as usual scenario, where no additional greenhouse gas reductions measures are implemented, municipal emissions are expected to increase from 6,399 to 6,494 tons $CO_2e$ between 2008 and 2015. This is a 1.5% increase over 2008 levels and a 0.5% increase over 1995 levels. Figure14, below, shows the forecast of emissions based on a business as usual scenario for the municipal government along with the emissions levels needed to achieve the goal of reducing emissions to 20% below 1995 levels by 2015. Figure 15 shows the municipal emissions forecast by sector for 2015. It is important to note that these forecasts do not take into account any of the emissions reduction measures that have been implemented since 2008, which includes the Energy contract with Honeywell and the hydro-electric generation at the water supply facility, among many others.

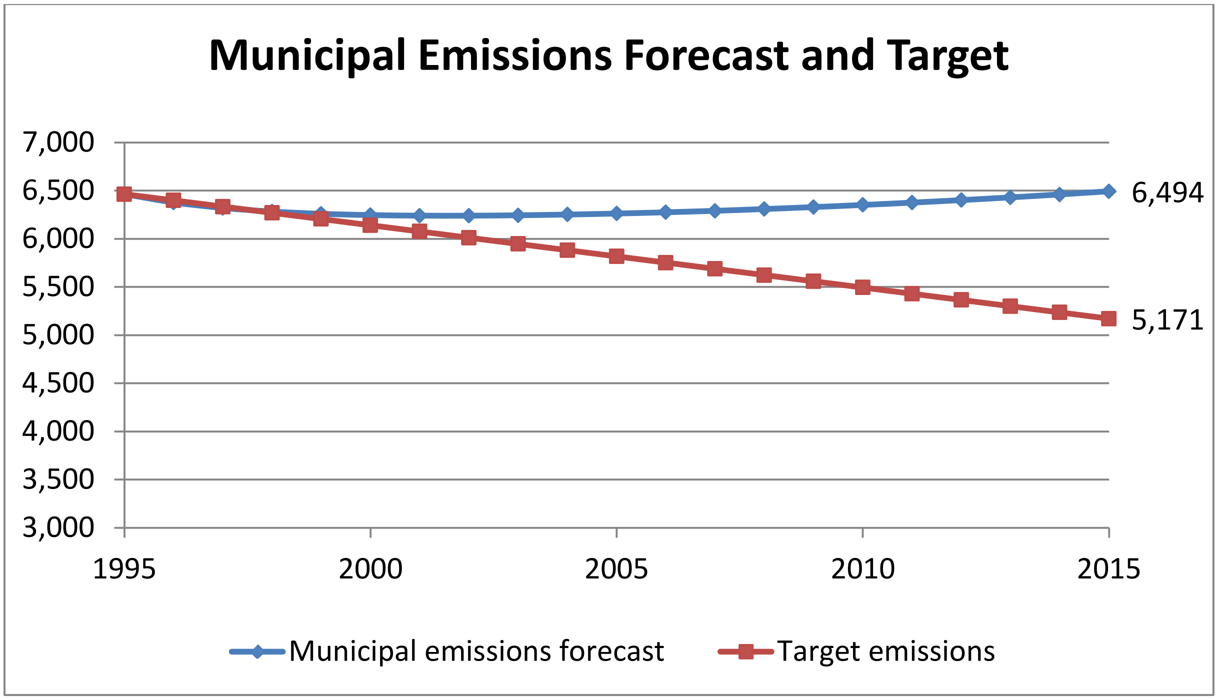


**Figure 13. City of Keene municipal emissions forecast and emissions reduction target.**

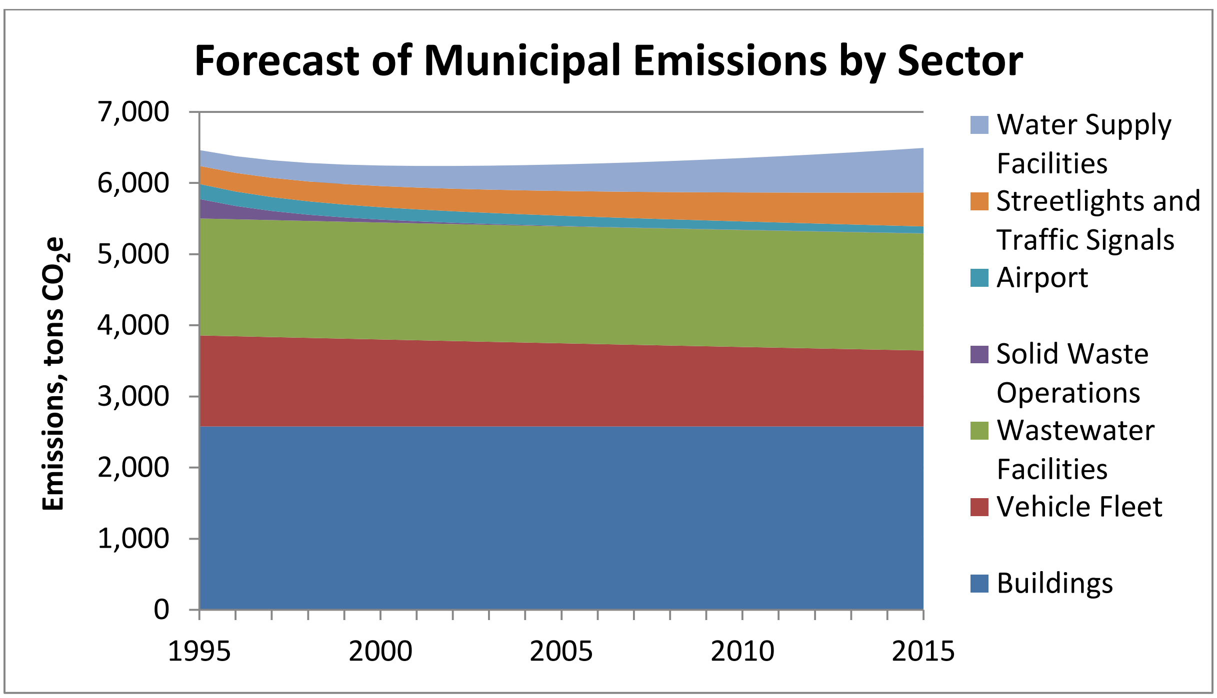


**Figure 14. City of Keene municipal emissions forecasts under a business as usual scenario, by sector.**

## 5.2 Recommendations

Tracking progress made towards achieving greenhouse reduction goals is an integral step to reducing emissions. It provides feedback on the impacts of measures and policies, highlights areas of opportunity for reducing emissions, and serves as a way to keep greenhouse gas reduction goals fresh in the minds of the community and public officials. Therefore, it is recommended that the process of creating a greenhouse gas inventory be streamlined as much as possible. This will allow inventory reports to be produced more frequently, providing timely feedback on progress made towards achieving desired results.

In order to streamline the process, it is recommended that ClearPath, ICLEI's replacement software for CACP, be used for future greenhouse gas inventories. This software is cloud based and can be accessed by multiple users with data stored on the cloud. It has the ability to manage multiple inventories and generate comparative inventory reports, as well as provide integrated forecasting of emissions. This software is free for ICLEI members, and includes other benefits such as pre-loaded emissions factors and integrated climate action planning. Data from earlier inventories can be uploaded manually into ClearPath software, and it is recommended that this is done in order to help ensure compatibility between inventories.

Also, data collection should be automated as much as possible in order to reduce the time and effort needed to find appropriate data. For example, energy use data for municipal facilities and operations should be kept in one central location (if possible). Each time an inventory is completed, the data gathered should be saved along with details about the data sourcing and methodology. This will help reduce internal inconsistencies between inventories.

# 6. Conclusion

While both the municipal sector and the community as a whole have taken steps towards reducing emissions, this greenhouse gas report indicates that Keene is not on track to meet the greenhouse gas reduction targets of the 2004 Climate Action Plan. However, it is clear that progress has been made, especially for the municipal sector.

## 6.1 Community Wide Analysis

From the community wide analysis it is clear that significant land use changes and rapid development along with regional transportation patterns will have to be addressed in order to meaningfully reduce emissions. Population levels stayed relatively constant from 1995-2008 with a population growth rate of only about 4%. During the same period, the commercial/industrial sector saw significant growth, increasing energy use by 26.3% and emissions by 65%. This suggests that land use changes in Keene are occurring at a much faster rate than population growth, which is driving up per capita emissions. Therefore, measures that target efficient development patterns may have the most impact on community wide emissions.

## 6.2 Municipal Facilities and Operations

At the municipal level, further increases in energy efficiency will go a long way toward reducing emissions in all sectors, particularly for the buildings sector. Already, measures such installing a geothermal HVAC system at the Public Works Department, using biodiesel in the municipal fleet, replacing traffic signal lights with LEDs, implementing an internal paper recycling paper program, and undergoing an energy audit of city buildings are saving the City of Keene money and reducing emissions. Moving forward, the City of Keene should continue to show leadership through the implementation of additional emissions reductions measures.

## Appendix A: List of Acronyms and Definitions

**AADT** – Annual average daily traffic. A statistic defined as a year's worth of average daily traffic. It is determined by projecting average traffic count data for a road segment over a year.

**CACP** – Clean Air and Climate Protection software. Greenhouse gas emissions inventory, analysis, and forecasting software distributed and supported by ICLEI. The version used in this report is 2009 rev1.

**CCP** – Cities for Climate Protection. A transnational municipal network aimed at reducing urban greenhouse gas emissions.

**CO2e** – Carbon dioxide equivalent. A measure used to compare the emissions from various greenhouse gases based upon their global warming potential (GWP). CO2 is used as a reference point because it is the most common greenhouse gas, but not the most powerful.

**EIA** – Energy Information Administration (United States). A division of the federal Department of Energy.

**GHG** – Greenhouse gas. A gas with significant radiation-trapping effects in the atmosphere. They typically allow light and other high-energy radiation through the atmosphere, but trap infrared and other low-energy radiation (heat) within the atmosphere.

**GWP** – Global warming potential. A multiplier used to compare the warming potential of gasses in the atmosphere to the warming potential of carbon dioxide. This is a relative measure determined by experimental results. The GWP of carbon dioxide, the baseline gas, is defined as 1.0.

**ICLEI-USA – ICLEI** - Local Governments for Sustainability, USA.

**LED** – Light-emitting diode. A lighting technology capable of greater energy efficiency than incandescent and fluorescent technologies.

**LGOP** – Local Government Operations Protocol. A common framework for municipalities to evaluate and report greenhouse gas emissions.

**MMBtu** – Million British thermal units. A unit of energy in common use for greenhouse gas emissions analyses and other fuel-related analyses. 1 MMBtu = 1,000,000 Btu = 10 therm = 293.08 kWh = 1.0551 GJ.

**OEP** – Office of Energy and Planning (New Hampshire). A state agency.

**VMT** – Vehicle miles traveled. A statistic determined by taking the average AADT for each road class, then multiplying by the total length of the road class. It is combined with a vehicle type distribution to produce community transportation emissions.

# Appendix B: Methodology

## Part 1: General methodology

The City of Keene adopted its 2004 Local Action Plan in accordance with the Cities for Climate Protection Campaign, a program through ICLEI – Local Governments for Sustainability. This report updates the City's previous greenhouse gas emissions inventory with data from 2006, 2007, and 2008.

The results of two analyses are contained in this report. The first, a community wide analysis, used public data to profile Keene's energy use. The community wide analysis is intended to inform the community of overall trends in greenhouse gas emissions in Keene and provide a framework for emissions reduction efforts. The second, a municipal analysis, used data from the operations of Keene's government (the "City of Keene") to profile government operations in much greater detail. The municipal analysis adheres to the Local Government Operations Protocol.

### Local Government Operations Protocol (LGOP)

The Local Government Operations Protocol (LGOP)8 provides municipalities with a common framework to evaluate and report greenhouse gas emissions. Using a limited selection of equivalent analysis methods allows local governments to compare their results to other governments and to their own historical results.

The LGOP is a collaborative effort of ICLEI, the California Climate Action Registry, the California Air Resources Board, and the Climate Registry. Each of these organizations approved the LGOP in July of 2009.Two levels of rigor are defined by the LGOP:

1. Full inventory: A full inventory is an investigation into all possible sources of greenhouse gas emissions; a full inventory must follow every recommended method contained within the LGOP.
2. Quick inventory: A quick inventory is any LGOP-compliant inventory that does not follow every recommended method of the LGOP.

The City of Keene's 2006-2008 greenhouse gas emissions inventory is a quick inventory. Differences between this inventory and the recommended full inventory methods are described in the methodology sections to follow.

### Base year and background analysis years

The "base year" for any analysis of change over time is the first year of analyzed data. All measures of success are relative to the base year. In Keene's first greenhouse gas emissions inventory, 1995 was chosen as the base year for analysis. To maintain consistency, 1995 remains the base year in this analysis.

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[8] Local Government Operations Protocol, version 1.

There have been some changes in greenhouse gas emissions inventory methods since the first analysis. To the extent possible, the prior data has been re-analyzed using the current methods and tools. Assumptions and estimates originally made for the 1995 analysis have been preserved where no demonstrably better choice is available.

### CACP software

Energy use information was translated into emissions information using ICLEI-USA's Clean Air and Climate Protection software (CACP)9. Details of the calculations CACP performs are available within the LGOP document. CACP provides a consistent interface for entry and management of the energy use information, fuel density information, and emissions factors required by the LGOP equations.

In addition to analyzing historical data, CACP provides a framework for forecasting future emissions. The software allows potential emissions reductions from specific mitigation measures to be quantified and added into the future emissions forecast. CACP partitions emissions into the categories recommended by the Local Government Operations Protocol (LGOP).

## Part 2: Community wide inventory methodology

### Sector definitions and data sources

Keene's community wide greenhouse gas emissions inventory is categorized into four major sectors: Residential, Commercial/Industrial, Transportation, and Solid Waste.

The community wide inventory relies on publicly available data assembled by the U.S. Census Bureau, the U.S. Energy Information Administration (US EIA), the State of New Hampshire Office of Energy and Planning, the State of New Hampshire Department of Transportation, and the Southwest Regional Planning Commission. In all sectors, data from the previous inventory years was recalculated using the current methods in order to provide a fair comparison between years and sectors.

### Residential and commercial/industrial sectors

Energy use data was obtained from the United States Department of Energy's Energy Information Administration (DOE EIA), the United States Census Bureau ("the Census"), and the State of New Hampshire Office of Energy and Planning (NH OEP). NH Gas provided aggregate data on utility propane air usage, and Public Service of New Hampshire provided aggregate data on electricity usage. The data sources applicable to the residential and commercial/industrial sectors are necessarily statistical in nature; therefore, for this purpose, results in the residential and commercial/ industrial sectors should be considered as a synthesis of estimates rather than an analysis of measurements. The commercial and industrial sectors were combined in this report due to the infeasibility of separating them for the analysis.

[9] Clean Air and Climate Protection 2009 Software, version 2.1, June 2009. Tables release date: 20090605.

For electricity, aggregate usage data was divided proportionally between the residential and commercial/industrial sectors according to Keene-specific demographic data for individuals, households, and businesses and adjustments to estimates made for the 1995 inventory. The proportions of the division were determined primarily by household data (for the residential sector) and business size and type data (for the commercial/industrial sector). Propane air data was classified appropriately for the analysis and required no manipulation. For other fuel types, regional average usage data per household and business usage class was multiplied by Keene-specific demographic data.

Wood heat was included in the inventory for the first time with this report. Wood consumption by households is variable based on housing characteristics, local microclimate, and heating technology; for this analysis, averages supplied by Census data (for Cheshire County) and UNH (for New Hampshire) served to provide a reasonable estimate. Many households using wood heat also tend to employ a mix of heating fuels. Local wood suppliers were unable to provide estimates of market share or customer locations. The wood heat portion of this analysis should be considered a rough estimate; local variations and wood quality are significant factors and cannot be confidently quantified without a survey.[10]

Usage estimates for energies other than electricity and propane air are based primarily on statistics for heating. Fuels used for activities and processes (such as gas lawn mowing, gas welding, or sugaring) other than heating are not reasonably quantifiable from public information and have therefore been excluded from this analysis.

### Transportation

Vehicle and energy use data were obtained from the United States Census Bureau, the State of New Hampshire Department of Transportation (NH DOT), the Southwest Regional Planning Commission (SWRPC), and ICLEI-USA. Emissions coefficients for transportation fuels and vehicle models were provided by ICLEI. Distribution of vehicle models was assumed to be generally in keeping with regional statistics. Emissions due to operation of traffic signals, streetlights, and other public services are counted within the municipal inventory.

The general method for calculating community transportation emissions is to multiply the Annual Average Daily Traffic (AADT) for each road class by the length of each road class. The result is Vehicle Miles Traveled (VMT). VMT is then multiplied, for each vehicle class, by emissions coefficients specific to that vehicle class. AADT was obtained from SWRPC and NH DOT. As these figures differed significantly, SWRPC data was used due to its greater completeness and longer time series. The NH DOT data incorporated segment lengths, which were used to verify and adjust segment lengths carried over from the previous inventory. Because SWRPC does not perform traffic counts for every measured segment in every year, unmeasured segments in each inventory year were filled via linear

[10] Wu 2005.

interpolation from surrounding years. Uncounted years at the beginning or end of the record were set equal to the nearest neighboring year.

### Explanation of Revisions to Previous Inventory

The previous inventory reported a significantly lower number for transportation emissions, which had the effect of increasing the relative share of the residential and commercial/industrial sectors. The main difference between the previous inventory and this report is based on differing methods for calculating Vehicle Miles Traveled (VMT), the core statistic behind transportation emissions. The values for 1995 contained within this report were developed using the current methods to ensure comparability.

The primary difference between the two inventories was produced by the use of complete Annual Average Daily Traffic (AADT) data in this inventory. This inventory used a year of 365 days, while the previous inventory used a year of 330 days to compensate for lower weekend traffic. Compensation for weekend traffic differences, however, is already included in the Annual Average Daily Traffic (AADT) numbers, the second factor of VMT. AADT is based on traffic counts, but traffic counts are not performed for every road segment in every year. For road segments with missing values in a given year, this inventory used interpolated values from surrounding years, which provided an AADT estimate for every road segment for each year in the inventory.

### Solid waste

Solid waste data were obtained from the City of Keene Public Works Department, the New Hampshire Office of Energy and Planning, the United States Environmental Protection Agency (US EPA), and ICLEI-USA.

Solid waste emissions were calculated by dividing total waste stream into proportions by type, then multiplying the results for each type by an emissions coefficient specific to the disposal technology. The City of Keene's solid waste operation utilizes on- and off-site recycling, managed landfill at the Rochester Turnkey Landfill (for construction debris), and controlled incineration at the Claremont Wheelabrator (all other waste).

The City of Keene tracks waste material quantities, by category, entering its recycling stream. These quantities are distributed similarly to national averages compiled by US EPA. Since the City does not track the proportion of materials in its two non-recycling waste streams, and given Keene's similarity to national trends, the recycling waste stream was used to compute the non-recycled waste stream based on the US EPA statistics.[11] The differences between Keene's recycled waste and the national profile were computed and used to adjust the non-recycled waste proportions of the national profile based on a linear weighting of Keene's overall waste stream.

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[11] This data was retrieved from the EPA 2007 Municipal Solid Waste Study, found at: http://www.epa.gov/waste/nonhaz/municipal/pubs/msw07-rpt.pdf

Emissions due to operation of Keene's solid waste facilities are counted within the municipal inventory. Transportation emissions due to export of waste to the Claremont, NH, Wheelabrator incinerator and the Rochester, NH, Turnkey Landfill (construction debris only) are not considered in this analysis.

### Explanation of Solid Waste Emissions and Sequestration

Within the CACP 2009 analysis software, landfilling is considered a method of sequestering carbon, and therefore typically results in negative emissions (an offset to emissions). For this report, only emissions from the solid waste sector were included; sequestration due to landfilling was not used to offset emissions in order to be consistent with other sectors that do not consider sequestration in emissions calculations. Table 5 shows solid waste emissions, total sequestration, net sequestration (found by balancing emissions against total sequestration), and emissions potential, which shows how many emissions would result if the whole waste stream were incinerated. This last value provides context for the waste stream but does not represent actual emissions.

| Solid Waste Emissions and Sequestration, tons $CO_2e$ | 1995 | 2006 | 2007 | 2008 |
|---|---|---|---|---|
| Emissions | 37 | 9,473 | 5,606 | 10,572 |
| Total Sequestration | -14,061 | -5,928 | -3,508 | -6,615 |
| Net Sequestration | -14,024 | 3,545 | 2,098 | 3,956 |
| Emissions Potential | 14,098 | 15,400 | 9,114 | 17,187 |

**Table 5. Solid waste emissions and sequestration values; red indicates negative emissions.**

## Part 3: City of Keene government inventory methodology

### Scope of responsibility

One of the most important aspects of the Local Government Operations Protocol (LGOP) used in the government analysis is its handling of responsibility for emissions. Emissions are classified into one of three scopes depending on the degree of control the City of Keene exerts over the source of the emissions. This classification system is immediately useful because it helps to prioritize potential improvements.

### Direct control

The essential concept within the three Scope definitions is control: if the City of Keene controls the *cause* of the emissions directly, then the City of Keene can control the emissions. For example, the City of Keene owns a landfill gas reclamation and electricity generation system that is about 75% efficient. Methane that escapes into the air is an emission that is directly controlled by the City. These directly controlled emissions are the best opportunities for the City to reduce its emissions.

### Indirect control

Indirectly influenced emissions are potential targets for reduction efforts, but the City cannot simply reduce these emissions as a matter of business – outside cooperation is necessary. For example, reducing employee commute emissions through ridesharing would reduce emissions, but employees would need to first work out the details and then stick to the commitment.

The three scopes of responsibility in the LGOP (Scope One, Scope Two, and Scope Three) allow different, sometimes overlapping entities (such as cities and businesses) to add their inventory results together without counting emissions more than once. Under the LGOP framework, emissions classified as Scope One for any participant cannot, by definition, be classified as Scope One emissions for any other participant. Summing the Scope One emissions of all participants is therefore a safe method of producing a total.

### *Scope One emissions*

Scope One emissions are defined as direct emissions controlled by the City of Keene. For example, the City does not share responsibility for its vehicle fleet with any other entity. Vehicles produce direct emissions: when a combustion engine is operating, exhaust is released; when the engine is off, no exhaust is produced. When the City chose to replace some vehicles with hybrid gasoline-electric models, it reduced its Scope One emissions.

### *Scope Two emissions*

Scope Two emissions are specific indirect emissions controlled by the City; Scope Two is restricted to "indirect greenhouse gas emissions associated with the consumption of purchased or acquired electricity, steam, heating, or cooling."[12] The electricity the City of Keene purchases from the utility grid falls under Scope Two emissions. While the City has control over how much electricity is drawn from the grid, the electricity is produced elsewhere (causing emissions elsewhere) and the electricity production is not under the City's control. Therefore grid electricity usage results in Scope Two emissions.

### *Scope Three emissions*

Scope Three emissions are indirect emissions excluded from Scope Two.
For example, the emissions resulting from municipal solid waste collected from and exported by Keene to solid waste facilities elsewhere, are Scope Three emissions. Since the City of Keene does not own its employees' personal vehicles, the emissions associated with employee commutes are Scope Three emissions.

## Data sources

The primary data source for the municipal government greenhouse gas emissions inventory was the Finance Department of the City of Keene. As the central repository for all cost data, the Finance Department was able to provide a consistent data set on energy costs that had been reliably updated in cases of billing error.

[12] Local Government Operations Protocol, version 1, Ch. 4 Sec. 1 (pg. 22).

To determine energy quantities, the Finance data was linked to base rate and variable rate information for each energy type. Base cost was subtracted when appropriate, and the remaining (variable) cost was divided by the price per unit (adjusted by rate class) for the energy type at the date of purchase. Figures for cost of energy include the entire cost (both base and variable).

## Sector Definitions

The government analysis is split into seven sectors: Buildings, Vehicle Fleet, Wastewater Facilities, Solid Waste Operations, Airport, Streetlights and Traffic Signals, and Water Supply Facilities.

### Buildings

The buildings sector includes all buildings and other stationary facilities not specifically included in any other sector. Water delivery, wastewater, and solid waste facilities are single-function and are therefore included in separate sectors. Building data was obtained from City of Keene Buildings, Parks & Recreation Director Brian Mattson.

### Vehicle fleet

The municipal fleet is defined as the mobile portion 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. Fleet fuel use data was not derived from Finance data because the data obtained directly from Fleet Services was more detailed and therefore more suitable for calculating emissions output. Municipal fleet data was obtained from City of Keene Fleet Services Superintendent Steve Russell.

### Wastewater Treatment

Wastewater treatment includes emissions from the operation of the Wastewater Treatment Plant at 420 Airport Road, the pumping station at 176 Martell Court, and operation of the sewer system. Emissions from wastewater treatment were calculated as a function of the amount of electricity required for operations.

### Solid waste Operations

Within the municipal emissions inventory, solid waste represents the emissions from the City of Keene's solid waste operation, as opposed to the emissions associated with the waste itself. There was insufficient data to calculate the municipal contribution to the total waste stream for the City of Keene, so this is counted within the community wide analysis. Emissions associated with the solid waste facilities primarily result from escapes and incompletely burned methane at the landfill gas reclamation and electricity generation system. Methane release was calculated from overall system efficiency (75%), overall electrical generation statistics, and the total amount of landfill gas burned by the generator.

### Airport

The airport sector includes emissions from the Airport building at 80 Airport Road, the outdoor lights and beacons, and maintenance of the terminals. Emissions from airport facilities were calculated as a function of the amount of electricity required for operation. Airport data was obtained from Airport Director Ed Mattern.

### Streetlights and Traffic Signals

Emissions from streetlights were calculated as a function of the amount of electricity required for operation. Streetlight and Traffic Signal data were obtained through the Finance Department of the City of Keene.

### Water Supply

The Water Supply Sector encompasses emissions from the Water Treatment Facility at 555 Roxbury Road as well as emissions resulting from water supply and delivery. Emissions from water delivery were calculated as a function of the amount of electricity required for operations.

## Appendix C: Emissions Coefficients

**Table 6. Fuel Emission Factors**

| Fuel | Emissions Unit | Per Energy Unit | CO2 Coefficient |
|---|---|---|---|
| Fuel Oil (#1 2 4) | (kg) | (MMBtu) | 73.15 |
| Fuel Oil (#1 2 4) ULSD | (kg) | (MMBtu) | 73.15 |
| Kerosene | (kg) | (MMBtu) | 72.31 |
| Nat Gas 1000 to 1025 Btu per cf | (kg) | (MMBtu) | 52.91 |
| Nat Gas 1025 to 1050 Btu per cf | (kg) | (MMBtu) | 53.06 |
| Nat Gas 1050 to 1075 Btu per cf | (kg) | (MMBtu) | 53.46 |
| Nat Gas 1075 to 1100 Btu per cf | (kg) | (MMBtu) | 53.72 |
| Nat Gas 975 to 1000 Btu per cf | (kg) | (MMBtu) | 54.01 |
| Nat Gas gt 1100 Btu per cf | (kg) | (MMBtu) | 54.71 |
| Natural Gas | (kg) | (MMBtu) | 53.06 |
| Natural Gasoline | (kg) | (MMBtu) | 66.88 |
| Other Oil gt 401 deg F | (kg) | (MMBtu) | 78.8 |
| Propane | (kg) | (MMBtu) | 63.07 |
| Residential Coal | (kg) | (MMBtu) | 95.33 |
| Residual Fuel Oil | (kg) | (MMBtu) | 78.8 |
| Stationary Gasoline | (kg) | (MMBtu) | 70.88 |
| Stationary LPG | (kg) | (MMBtu) | 63.16 |
| Biodiesel (B100) | (kg) | (US gal) | 15.76 |
| Compressed Natural Gas | (kg) | (MMBtu) | 53.057 |
| Diesel | (kg) | (MMBtu) | 73.15 |
| Diesel ULSD | (kg) | (MMBtu) | 73.15 |
| Ethanol (E100) | (kg) | (US gal) | 0 |
| Gasoline | (kg) | (MMBtu) | 70.88 |
| Liquefied Natural Gas | (kg) | (US gal) | 4.46 |
| LPG | (kg) | (MMBtu) | 63.16 |
| Methanol | (kg) | (US gal) | 4.1 |
| OFF ROAD Aviation Gasoline | (kg) | (US gal) | 8.32 |
| OFF ROAD Diesel | (kg) | (US gal) | 10.15 |
| OFF ROAD Diesel ULSD | (kg) | (US gal) | 10.15 |
| OFF ROAD Gasoline | (kg) | (US gal) | 8.81 |
| OFF ROAD Jet Fuel | (kg) | (US gal) | 9.57 |
| OFF ROAD Residual Fuel Oil | (kg) | (US gal) | 11.8 |

**Table 7. Electricity Emission Factors**

| Year | Emissions Unit | Per Energy Unit | CO2 Coefficient | N2O Coefficient | CH4 Coefficient | NOx Coefficient | Sox Coefficient | CO Coefficient | VOC Coefficient | PM10 Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | (lbs) | (MWh) | 897.1 | 0.01701 | 0.08649 | 0.9331 | 3.997 | 1.145 | 0.1303 | 1.085 |
| 1996 | (lbs) | (MWh) | 897.1 | 0.01701 | 0.08649 | 0.9331 | 3.997 | 1.145 | 0.1303 | 1.085 |
| 1997 | (lbs) | (MWh) | 897.1 | 0.01701 | 0.08649 | 0.9331 | 3.997 | 1.145 | 0.1303 | 1.085 |
| 1998 | (lbs) | (MWh) | 897.1 | 0.01701 | 0.08649 | 0.9331 | 3.997 | 1.145 | 0.1303 | 1.085 |
| 1999 | (lbs) | (MWh) | 897.1 | 0.01701 | 0.08649 | 0.9331 | 3.997 | 1.145 | 0.1303 | 1.085 |
| 2000 | (lbs) | (MWh) | 897.1 | 0.01701 | 0.08649 | 0.9331 | 3.997 | 1.145 | 0.1303 | 1.085 |
| 2001 | (lbs) | (MWh) | 897.1 | 0.01701 | 0.08649 | 0.9331 | 3.997 | 1.145 | 0.1303 | 1.085 |
| 2002 | (lbs) | (MWh) | 897.1 | 0.01701 | 0.08649 | 0.9331 | 3.997 | 1.145 | 0.1303 | 1.085 |
| 2003 | (lbs) | (MWh) | 897.1 | 0.01701 | 0.08649 | 0.9331 | 3.997 | 1.145 | 0.1303 | 1.085 |
| 2004 | (lbs) | (MWh) | 908.902 | 0.0153 | 0.0798 | 0.7941 | 1.702 | 1.189 | 0.1339 | 1.05 |
| 2005 | (lbs) | (MWh) | 927.68 | 0.017 | 0.08649 | 0.7635 | 1.543 | 1.185 | 0.1332 | 1.03 |
| 2006 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |
| 2007 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |
| 2008 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |
| 2009 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |
| 2010 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |
| 2011 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |
| 2012 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |
| 2013 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |
| 2014 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |
| 2015 | (lbs) | (MWh) | 927.7 | 0.017 | 0.086 | 0.764 | 1.543 | 1.185 | 0.133 | 1.03 |

**Table 8. Solid Waste Emission Factors.**

| Type Name | Disposal Tech Name | Emissions Unit | Per Waste Unit | Methane Coefficient | Sequestered at site Coefficient |
|---|---|---|---|---|---|
| Paper Products | Managed Landfill | (tons) | (tons) | 2.138262868 | -0.9279254 |
| Food Waste | Managed Landfill | (tons) | (tons) | 1.210337473 | -0.08068917 |
| Plant Debris | Managed Landfill | (tons) | (tons) | 0.685857901 | -0.84723623 |
| Wood/Textiles | Managed Landfill | (tons) | (tons) | 0.605168736 | -0.84723623 |
| All Other Waste | Managed Landfill | (tons) | (tons) | 0 | 0 |
| Paper Products | Controlled Incineration | (tons) | (tons) | 0.080689165 | 0 |
| Food Waste | Controlled Incineration | (tons) | (tons) | 0.080689165 | 0 |
| Plant Debris | Controlled Incineration | (tons) | (tons) | 0.080689165 | 0 |
| Wood/Textiles | Controlled Incineration | (tons) | (tons) | 0.080689165 | 0 |
| All Other Waste | Controlled Incineration | (tons) | (tons) | 0.484134989 | 0 |

## Appendix D: Supporting tables

**Table 9. Community wide energy use, in MMBtus, for 1995 and 2006-2008.**

| Sector | 1995 | 2006 | 2007 | 2008 |
|---|---|---|---|---|
| Transportation | 2,719,072 | 2,590,189 | 2,581,093 | 2,565,003 |
| Commercial | 783,274 | 662,223 | 1,005,769 | 989,299 |
| Residential | 791,615 | 1,048,443 | 1,048,498 | 1,031,328 |
| Government | 64,413 | 59,786 | 59,878 | 61,225 |
| Solid Waste (emissions) | N/A | N/A | N/A | N/A |
| **Grand Total** | **4,358,374** | **4,360,641** | **4,695,238** | **4,646,855** |

**Table 10. Community wide emissions, in tons $CO_2e$, for 1995 and 2006-2008.**

| Sector | 1995 | 2006 | 2007 | 2008 |
|---|---|---|---|---|
| Transportation | 220,027 | 207,059 | 206,361 | 205,102 |
| Commercial | 68810 | 112173 | 115733 | 113654 |
| Residential | 67,281 | 90559 | 90733 | 89238 |
| Government | 6,464 | 6,320 | 6,184 | 6,399 |
| Solid Waste (emissions) | 37 | 9,473 | 5,606 | 10,572 |
| **Grand Total** | **362,619** | **425,584** | **424,617** | **424,965** |

**Table 11. Municipal energy use, in MMBtu, for 1995 and 2006-2008.**

| Sector | 1995 | 2006 | 2007 | 2008 |
|---|---|---|---|---|
| Buildings, Parks & Rec | 29,785 | 24,905 | 27,571 | 26,237 |
| Vehicle Fleet | 14,774 | 11,708 | 11,230 | 13,176 |
| Wastewater Facilities | 10,074 | 11,393 | 11,602 | 10,691 |
| Solid Waste Operations | 3,405 | 2,266 | 2,261 | 2,259 |
| Airport | 2,776 | 1,208 | 1,215 | 1,332 |
| Streetlights & Traffic Signals | 1,917 | 3,368 | 2,715 | 3,109 |
| Water Supply Facilities | 1,682 | 4,938 | 3,284 | 4,421 |
| **Grand Total** | **64,413** | **59,786** | **59,878** | **61,225** |

**Table 12. Municipal emissions, in tons $CO_2e$, for 1995 and 2006-2008.**

| Sector | 1995 | 2006 | 2007 | 2008 |
|---|---|---|---|---|
| Buildings, Parks & Rec | 2,578 | 2,441 | 2,681 | 2,568 |
| Vehicle Fleet | 1,280 | 1,015 | 968 | 1,135 |
| Wastewater Facilities | 1,644 | 1,658 | 1,622 | 1,637 |
| Solid Waste Operations | 274 | 3 | 2 | 2 |
| Airport | 211 | 125 | 124 | 128 |
| Streetlights & Traffic Signals | 254 | 461 | 372 | 426 |
| Water Supply Facilities | 223 | 617 | 415 | 503 |
| **Grand Total** | **6,464** | **6,320** | **6,184** | **6,399** |

**Table 13. 2008 building sector emissions in tons $CO_2e$, ranked.**

| Facility or operation | Electricity | Fuel oil | Natural gas | Propane | Total emissions | Percent of sector |
|---|---|---|---|---|---|---|
| Garage / Police / Corrections | 394 | 706 | -- | -- | 1100 | 42.8% |
| City Hall | 246 | 64 | -- | -- | 310 | 12.1% |
| Library | 105 | 170 | -- | -- | 275 | 10.7% |
| Recreation Center | 84 | 163 | -- | -- | 247 | 9.6% |
| Central Fire Station | 45 | 87 | -- | -- | 132 | 5.1% |
| Fleet Management | 31 | 45 | 6 | 46 | 128 | 5.0% |
| Parks Maintenance | 62 | 20 | -- | -- | 82 | 3.2% |
| Pond Mansion | 0 | 66 | -- | -- | 66 | 2.6% |
| West Keene Fire Station | 30 | 17 | -- | -- | 47 | 1.8% |
| Transportation Center | 25 | 17 | -- | -- | 42 | 1.6% |
| Downtown Maintenance | 36 | 0 | -- | -- | 36 | 1.4% |
| Wells Street Parking | 27 | 0 | -- | -- | 27 | 1.1% |
| Summer Knight Chapel | 0 | 23 | -- | -- | 23 | 0.9% |
| Vernon Street Law Office | 6 | 15 | -- | -- | 21 | 0.8% |
| Fire Station Maintenance | 6 | 11 | -- | -- | 17 | 0.7% |
| Cemeteries Operations | 5 | 11 | -- | -- | 16 | 0.6% |
| Winter Maintenance | 2 | 0 | -- | -- | 2 | 0.1% |

**Table 14. Global warming potentials for greenhouse gasses assessed in this report.**

| Common Name | Formula | GWP |
|---|---|---|
| Carbon dioxide | $CO_2$ | 1 |
| Methane | $CH_4$ | 21 |
| Nitrous oxide | $N_2O$ | 310 |
| Sulfur hexafluoride | $SF_6$ | 23,900 |
| **Hydrofluorocarbons** | | |
| HFC-23 | $CHF_3$ | 11,700 |
| HFC-32 | $CH_2F_2$ | 650 |
| HFC-41 | $CH_3F$ | 150 |
| HFC-43-10mee | $C_5H_2F_{10}$ | 1,300 |
| HFC-125 | $C_2HF_5$ | 2,800 |
| HFC-134 | $C_2H_2F_4$ | 1,000 |
| HFC-134a | $C_2H_2F_4$ | 1,300 |
| HFC-143 | $C_2H_3F_3$ | 300 |
| HFC-143a | $C_2H_3F_3$ | 3,800 |
| HFC-152 | $C_2H_4F_2$ | 43* |
| HFC-152a | $C_2H_4F_2$ | 140 |
| HFC-161 | $C_2H_5F$ | 12* |
| HFC-227ea | $C_3HF_7$ | 2,900 |
| HFC-236cb | $C_3H_2F_6$ | 1,300* |
| HFC-236ea | $C_3H_2F_6$ | 1,200* |
| HFC-236fa | $C_3H_2F_6$ | 6,300 |
| HFC-245ca | $C_3H_3F_5$ | 560 |
| HFC-245fa | $C_3H_3F_5$ | 950* |
| HFC-365mfc | $C_4H_5F_5$ | 890* |
| **Perfluorocarbons** | | |
| Perfluoromethane | $CF_4$ | 6,500 |
| Perfluoroethane | $C_2F_6$ | 9,200 |
| Perfluoropropane | $C_3F_8$ | 7,000 |
| Perfluorobutane | $C_4F_{10}$ | 7,000 |
| Perfluorocyclobutane | c-$C_4F_8$ | 8,700 |
| Perfluoropentane | $C_5F_{12}$ | 7,500 |
| Perfluorohexane | $C_6F_{14}$ | 7,400 |