Town of Stoughton

Greenhouse Gas Emissions Baseline Study

Stoughton Energy & Sustainability Committee

May 2011

Executive Summary

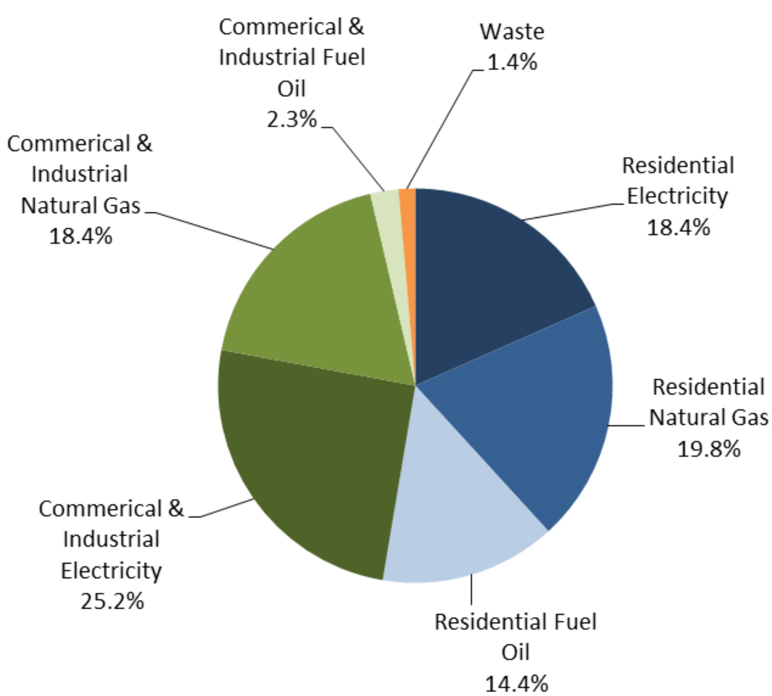
The Stoughton Energy & Sustainability Committee (ESC) has developed this report to serve as a benchmarking and planning assistance tool for the Town of Stoughton, Massachusetts. The report provides an overview of the calendar year 2009 greenhouse gas (GHG) emissions originating from Stoughton, water consumption, and wastewater and solid waste generation. The ESC analyzed data for the entire town and for municipal services (e.g., fire protection, schools). The main objectives of this study are as follows:

1. Identify the largest sources of GHG emissions and resource consumption;
2. Determine the resource impacts of the town (electricity, natural gas, water, wastewater, solid waste, and transportation);
3. Provide recommendations to town leadership and other parties interested in reducing Stoughton's GHG footprint and resource consumption;
4. Identify gaps in available information that limit the precision of studies such as this one; and
5. Determine the most effective next steps for the committee in helping the town become more sustainable.

Greenhouse Gas Emissions

The figure below illustrates the distribution of non-transportation GHG emissions for the town. Emissions from heating fuels are the largest emissions source, followed by commercial electricity use and residential electricity use. Non-transportation GHG emissions in 2009 are estimated to be 160,635 tons.

Distribution of Non-Transportation Greenhouse Gas Emissions



Town-Wide Resource Impacts

The typical Stoughton household paid $1,307 for electricity and $930 for natural gas or $1,647 for heating oil[1]. The average person used 52.4 gallons of water per day, produced 52.4 gallons of wastewater per day, produced 713 pounds of trash, and recycled 57 pounds of glass, plastic, paper, and metal. The average person in town created 3.11 tons of GHG through operation of their homes and appliances.

Commercial customers spent, in aggregate, $13.2 million on electricity, $1.0 million on heating oil and $5.2 million on natural gas. This is equivalent to 67,271 kWh and 5,447 therms per business worth $17,943 annually. The Committee was not able to obtain solid waste production information for commercial and industrial businesses.

Transportation data sources available to the Committee were limited. While data is available for vehicle miles traveled within Stoughton on state highways, this data does not link emissions to proactive choices made by Stoughton's residents. Future GHG emissions and resource use studies should incorporate this information.

Water use in 2009 was 721.4 million gallons, including 8% distribution losses and 6% for town operations. Residential consumption has remained relatively low based on withdrawal records and reports filed with the Massachusetts Department of Environmental Protection (52.4 gallons per person per day). The town's record keeping for the population served, the number of private wells, and consumption by end use type could be developed to provide more accurate measurements of consumption.

Wastewater generation in 2009 is 1,571 million gallons for the entire town, 89% of which was treated by the Massachusetts Water Resource Authority at Deer Island in Boston Harbor. Most of the flow going to Deer Island (61%) is from ground water infiltration or storm inflow. The town can save considerable money in MWRA fees by continuing to reduce inflow and infiltration.

Solid waste produced within the town is also a source of GHG emissions. The Stoughton DPW collected 9,691 tons of solid waste for disposal in 2009. Stoughton has a lower paper/cardboard/metal/ glass recycling rate than most nearby communities. The US EPA reports that the 2009 US municipal diversion rate is 33.8% (recyclables and compostable yard waste). Stoughton's diversion rate of 27%, including yard waste, is below the national average.

Municipal Services Resource Impacts

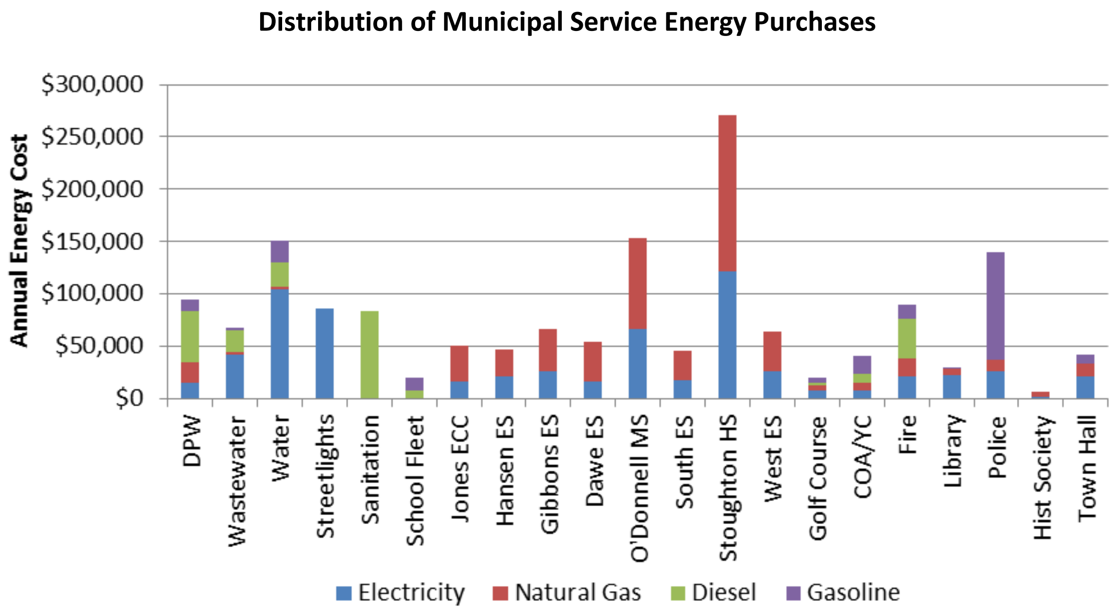
The Town of Stoughton government spent $1,654,628 on electricity, natural gas, and vehicle fuels in 2009, which represented approximately 3% of the town budget.

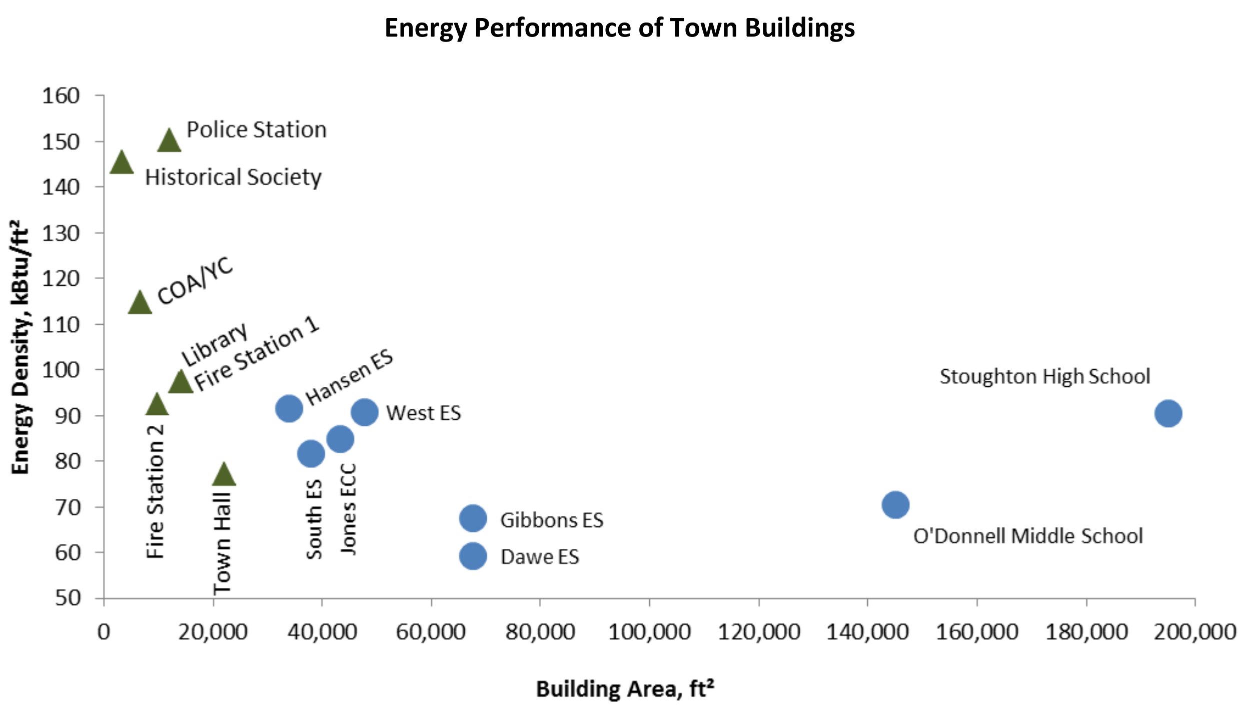
The study determined how energy consumption is distributed among the various town services. The distribution of energy expenditures is illustrated on the following page. Stoughton Public Schools consumes the most heating fuels (space heating), the DPW uses the most electricity (streetlights, pumping) and diesel fuel (sanitation, work trucks), while the police department uses the most gasoline.

The energy performance for regularly occupied, heated buildings was determined on the basis of thousand Btu per gross square foot of building floor are. Results are presented on the following page. These results suggest that the high school and the police station have poor energy performance relative to other

[1] These values assume an electrical rate of $0.1687/kWh, $1.21 per therm of natural gas, and $3.00 per gallon of oil

buildings and may indicate opportunities for improvement. Hansen, South, West Elementary Schools and Jones Early Childhood Center appear to present additional opportunities for improvement since they use more energy than Gibbons and Dawe Elementary Schools.





Recommendations

The study makes the following recommendations for reducing town-wide GHG emissions and resource impacts:

1. Increase residential and commercial participation in existing MassSave energy efficiency incentive programs administered by National Grid and Columbia Gas of Massachusetts. The following retrofit opportunities are likely to offer the greatest gains:
    a. Commercial lighting fixture upgrades and automatic controls
    b. Commercial ventilation control upgrades and high efficiency end-of-life HVAC unit replacement
    c. Residential weatherization improvements
    d. Residential heating equipment and appliance upgrades
2. Encourage the installation of solar technologies and participation in federal and state incentive programs as well as the solar renewable energy credit market.
3. Adopt the Stretch Energy Code to require new construction to be high performance.
4. Reduce commercial/industrial water consumption through education and outreach.
5. Increase residential waste diversion through increased recycling, increased composting, and reduced disposable waste through education and outreach.

The town can reduce its operating costs through the following recommendations:

6. Include life-cycle cost analyses when making planning and purchasing decisions.
7. Replace the steam systems at the high school and middle school with high efficiency hot water.
8. Implement recommendations of the recent energy efficiency scoping study performed by National Grid/B_2Q at Stoughton High School.
9. Actively pursue involvement in MassSave energy efficiency programs through National Grid and Columbia Gas to identify additional opportunities and implement cost effective upgrades.
10. Continue to reduce wastewater collection system infiltration and clarify irregularities in data.
11. Reduce fuel consumption by limiting idling time for DPW, police, and fire vehicles.
12. Implement an efficient vehicle purchasing policy for the town and schools, and phase out reuse of inefficient vehicles.

Stoughton ESC Next Steps

The Stoughton ESC plans to discuss the findings of this report with town leaders, department heads, and interested community groups. The committee plans to develop goals and timelines for implementation of different projects in collaboration with town entities. This study is the necessary first step in this process to ensure that future efforts are focused on areas that will have the greatest impact.

As this report was developed, ESC members identified opportunities for improved data gathering and processing. The Committee hopes to develop a recommendations report intended to facilitate regular updates to analyses developed as part of this study.

The Committee will continue to pursue Green Communities designation for Stoughton under the Massachusetts Department of Energy Resources' Green Communities Grant Program. Funds from this program are intended to be used for implementation of energy conservation projects.

Finally, the Committee hopes to develop an action plan to help focus the efforts of the ESC, other town committees, and public service groups in the community.

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The Authors

The Stoughton Energy & Sustainability Committee (ESC) is a citizen's advisory group to the Town's Board of Selectmen focusing on issues pertaining to energy consumption, greenhouse gas monitoring, water consumption, and wastewater generation. The Committee has developed this report over the course of the past year to serve as a benchmarking and planning assistance tool for the Town. Committee members, listed below, worked together to determine what information would be included and how it would be presented. Individual members then took on separate research projects based on personal interest, areas of expertise, and the needs of the committee. The development of this report has been a rewarding venture for all involved in that we gained deeper insights into the community we all share. Brief biographies of the committee members, a more developed description of the ESC, and a description of the committee's recent work are included in Appendix B.

David Billo, Committee Chairperson; Transportation and CO_2e Calculations
Mike Fisher, Committee Member; Electricity & Natural Gas
Patricia Hogan, Committee Member; Water & Wastewater
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Chapter 1: Study Background

> Scientists state unequivocally that the earth is warming. Climate change is happening, it is caused in large part by human activity, and it will have many serious and potentially damaging effects in the decades ahead. Greenhouse gas emissions from cars, power plants, and other human activities—rather than natural variations in climate—are the primary cause of contemporary global warming. Due largely to the combustion of fossil fuels, atmospheric concentrations of carbon dioxide (CO_2), the principal greenhouse gas, are at a level unequaled for at least 800,000 years.
>
> The consensus among climate scientists is that to avoid the most severe consequences of global warming, global emissions of greenhouse gases need to peak no later than 2015 and decline rapidly thereafter to a level between 50 and 85 percent below 2000 levels by 2050. Later in the century and beyond, emissions must continue to decline to near zero. Adapting to unavoidable climate change while simultaneously reducing emissions to these levels are major challenges that require unprecedented cooperation and participation across the world (1).
>
> *Pew Center on Climate "Climate Change 101" January 2009*

Governmental actions in response to climate change have been started at the international, federal, state, and local level. International efforts focused on the Kyoto Protocol in 2007 and the 2010 Copenhagen meeting have failed to achieve strong support for concerted international action due to competing international interests. However, in 2007 the US federal government passed the Energy Independence and Security Act (EISA) to respond to the need to reduce both energy consumption and greenhouse gas (GHG) emissions (2). Programs within EISA include:

- Reducing total energy use in federal buildings by 30% (compared to 2005) by 2015,
- Reducing fossil-fuel energy use relative to 2003 by 55% by 2010 and eliminating its use (100% reduction) by 2030, and
- Prohibiting federal agencies from leasing buildings that have not achieved EPA's Energy Star label.

Massachusetts has taken several important steps toward reducing GHG emissions. Massachusetts is one of the ten northeast state members in the Regional Greenhouse Gas Initiative (RGGI), a cap and trade auction in which utilities purchase permits to emit CO_2. The RGGI not only raises millions of dollars for renewable energy projects but also requires a 10% reduction in CO_2 emissions by utilities by 2018 (3). In 2008, the Global Warming Solutions Act was passed, which commits Massachusetts to reducing statewide CO_2 emissions by 80% below 1990 levels by 2050 (4, 5). Also in 2008, the Massachusetts legislature passed the Green Communities Act, which supports the development of renewable energy resources and creates a foundation for the new energy economy (5, 6).

Locally, cities and towns throughout the US and Massachusetts are moving forward in advance of state and federal programs to begin the process of reducing GHG emissions – both independently and through organizations such as ICLEI-USA (Local Governments for Sustainability, formerly International Council for

Local Environmental Initiatives) and the US Conference of Mayors. Many of Stoughton's neighbors, including Boston, Weymouth, New Bedford, Bridgewater, Dedham, Carver, Kingston, Marshfield, and Easton, have organized citizens' committees and joined statewide and national groups in an effort to begin the fight to reduce GHG emissions.

In the face of these actions by governments at all levels to respond to the challenges of climate change, the Stoughton Energy and Sustainability Committee (ESC), a citizen's advisory group to the Stoughton Board of Selectmen, was formed in 2009 and desires to assist in the following activities:

- Prepare Stoughton to meet the goals that will be required in the decades to come
- Position the town to take advantage of available funding programs,
- Assist the town in reducing the costs associated with inefficient energy use, and
- Provide information to town residents and agencies about sustainability, climate change, and energy and resource conservation.

A number of state, federal, and global initiatives require municipalities to understand and quantify their energy use and the associated GHG emissions. Therefore, one of the first steps needed is the production of a municipal energy consumption and GHG inventory baseline for the town. In addition to providing useful information for effective town management, such a baseline is also a prerequisite for many funding opportunities of interest to the Town of Stoughton.

1.1 Stoughton in 2011

The Town of Stoughton is a former mill/manufacturing town located approximately 20 miles south of Boston and 30 miles northeast of Providence, Rhode Island. Stoughton is abutted by the towns of Avon, Canton, Easton, Randolph, and Sharon and the city of Brockton. A regional map is provided in Appendix C, Map 1. With a population of approximately 27,169 persons in July of 2009, Stoughton is considered a medium-sized community, comprised primarily of residential, suburban homes. With a land area of 16.27 square miles, the town's population density is approximately 1,670 persons per square mile. Stoughton has a substantial land base zoned for commercial and industrial use. The major commercial and industrial areas are located adjacent to Route 24; along Routes 138, 139, and 27 (7, 8); and along the rail corridor between downtown and Canton. A zoning map is included in Appendix C, Map 2, and a land use description is provided in Map 3.

Stoughton is located within two river basins: 7.97 square miles are in the Neponset River basin, and 8.30 square miles are in the Taunton River basin. Stoughton is located on the East Branch of the Neponset River. The Neponset River flows in a northerly direction and ultimately discharges into Dorchester Bay. The Taunton River flows in a southerly direction and ultimately discharges into Narragansett Bay. Map 4 in Appendix C illustrates the division of town between these two watersheds.

Town services are divided between the Stoughton Public School Department and municipal government. In fiscal year 2009 (FY09), the town budget was $64.4 million. Expenditures for electricity and natural gas in FY09 represented 2.6% of the town budget, worth $1,654,628.

1.2 Community Planning Efforts

The Town of Stoughton has embarked on a number of planning initiatives to address the projected population of 32,712 in 2030, changes in community demographics, and anticipated gentrification of new residential areas (8). Table 1.2.1 below presents some examples of recent planning initiatives and the committees and boards that have participated in their development. As Stoughton looks forward to its future, the integration of sustainability strategies with other community planning efforts, e.g. smart growth strategies, is key to effective policy and infrastructure development.

Table 1.2.1
Recent Town of Stoughton Planning Initiatives

Board / Committee	Planning Initiative	Primary Purpose	Partners
Open Space Committee *Appointed: 7 Members*	Open Space & Recreation Plan (2007)	Town Planning	No outside consultants
Community Preservation Act Committee *Appointed: 9 Members*	Community Preservation Act (CPA) adopted in 2008	MA CPA Grant Funding Opportunities	Consultant assisting with plan creation
Conservation Commission *Appointed: 7 Members*	Wetlands Protection Bylaw, amended in 2009	MA Wetlands Preservation Requirements	No outside consultants
Housing Advisory Committee *Appointed: 8 Members*	Affordable Housing Plan (2009)	Executive Order 519	Metropolitan Area Planning Council
Facilities Planning Committee *Appointed: 10 Members*	Town-wide Facilities Master Plan (2010)	Town Planning	Drummey Rosane Anderson, Inc.
Energy & Sustainability Committee *Volunteer: 7 Members*	Energy & Resource Use Inventory (2011)	GHG Reduction Effort Planning	No outside consultants
School Building Feasibility Study Committee *Volunteer: 11 Members*	School Building Feasibility Study	School Facility Planning for Future Construction	No outside consultants
South Coast Rail Advisory Committee *Appointed: 19 Members*	On-going	Represent community interests in regional planning effort	Various legal consultants

1.3 Rationale for This Study

Although climate change is a global issue, local governments will be key players in providing mitigation strategies that collectively will result in larger emission reduction effects. For example, local governments can impact local building codes, municipal utilities, land use, urban reforestation projects, waste management, transportation patterns, and environmental codes and practice. A local climate action plan provides a strategy for a town or city to move forward in the best interests of both its local citizenry and its global neighbors.

The US Environmental Protection Agency (US EPA) states that developing a greenhouse gas (GHG) emissions inventory provides local governments with the following benefits (10):

- Identification of the greatest sources of GHG emissions within their jurisdiction
- Understanding of emission trends
- Quantification of the benefits of activities that reduce emissions
- Establishment of a basis for developing a local action plan
- Tracking progress in reducing emissions
- Setting goals and targets for future reductions

Performing a GHG inventory and establishing an emissions baseline provides the basis for the development of a local climate action plan.

1.4 Massachusetts Global Warming Programs and Initiatives

The Commonwealth of Massachusetts has a number of programs and initiatives targeted at reducing the emissions of greenhouse gases and thus mitigating global warming. In 2007, Massachusetts joined the Regional Greenhouse Gas Initiative (RGGI),a cooperative joint program between the New England and Mid-Atlantic states to develop regional strategies to reduce the emission of CO_2 (3). The 2008 Global Warming Solutions Act (GWSA) established statewide GHG emissions reduction targets of between 10% and 25% below 1990 levels by 2020 and 80% below 1990 levels by 2050 (4, 5). In addition, the GWSA requires the Commonwealth to develop a number of regulations, a baseline of GHG emissions, projections for 2020 emissions, and reduction strategies that are to be implemented by 2020.

The Executive Office of Energy and Environmental Affairs (EOEEA) has established two advisory committees to help with the implementation of the GWSA: 1) the Climate Protection and Green Economy Advisory Committee and 2) the Climate Change Adaptation Advisory Committee. The first advisory committee, charged with making recommendations for reduction of GHG emissions, released its *Massachusetts Clean Energy and Climate Plan for 2020* in December 2010 (11). The plan establishes the most ambitious GHG emissions reduction target of 25% below 1990 levels by 2020 with proposals to establish new programs and enhance existing programs to achieve this target. The second advisory committee is concerned with making recommendations for adapting to the climate change that is occurring, even with reductions and mitigations in place.

Also, in 2008, the Greenhouse Communities Act (GCA) was promulgated to improve the Commonwealth's ability to meet the GWSA emission reduction targets. The GCA provides opportunities for cities and towns to implement energy efficiency and renewable energy strategies that will improve their emission profiles and thus the statewide profiles. The GCA is described in more detail in the next section.

1.5 Green Communities Grant Program

The 2008 Green Communities Act created a foundation to support many initiatives intended to move the state toward a clean energy future. One of the many requirements of the Act is the creation of a Green Communities grant program, through which cities and towns can receive funding to support locally identified projects that improve energy performance (12). The grant program is funded through proceeds from the Regional Greenhouse Gas Initiative (RGGI). Municipalities become designated as Green Communities if they can demonstrate compliance with the following five criteria:

1. Allow as-of-right siting (i.e., designating locations within the town that, once designated, will not require special permits) for alternative/renewable energy generation or manufacturing or research/development,
2. Permit responses for as-of-right facilities within one year of application,
3. Develop an energy use baseline for municipally owned and operating properties and create a plan to reduce energy use by 20% within 5 years,
4. Adopt fuel-efficient vehicle purchasing policies, and
5. Adopt an energy code that achieves a 20% reduction in energy use below standard energy code.

Grant award amounts for the first two rounds (2010 and 2011) have ranged between $125,000 and $1 million per town. Stoughton's Energy and Sustainability Committee (ESC) is currently working with the town to become a designated Green Community (12).

1.6 Energy Use Reduction Incentive Programs

Part of the 2008 Green Communities legislation involved the restructuring of the energy efficiency incentive programs that investor-owned utilities have been required to provide since 1990. The objective of the legislation is to create a common incentive system for all utilities. This system, called MassSave, is under the direction of the Massachusetts Department of Energy Resources (DOER). Part of the legislation is a requirement that the efficiency programs support all economically feasible upgrades to existing equipment and to incentivize the adoption of high efficiency technology in new construction that surpasses performance requirements stipulated by the energy code.

National Grid and Columbia (formerly Bay State) Gas are considered to be program administrators (PAs) for the MassSave program, and they serve as the primary contacts for town residents and businesses when pursuing incentives. Each PA commits to achieving specific energy savings each year as part of comprehensive three-year plans. The utilities have a large budget to carry out the objectives of the Green Communities Act, and they are looking for projects to incentivize. Stoughton’s government, residents, and commercial/industrial facility operators can benefit greatly from this source of funding.

Chapter 2: Town-wide Greenhouse Gas Emissions and Resource Use

The ESC has developed the following greenhouse gas (GHG) inventory for the Town of Stoughton. A GHG inventory is an accounting of greenhouse gases emitted to or removed from the atmosphere over a period of time in a particular area. Four principal greenhouse gases are considered:

- Carbon dioxide (CO_2): produced by high and low temperature combustion, decomposition
- Methane (CH_4): produced by anaerobic decomposition (wastewater collection, on-site treatment)
- Nitrous oxides (NO_x): produced by high temperature combustion (engines, incineration)
- Fluorinated gases: produced by manufacturing processes, and from leaks (cooling systems)

The international standard practice is to express greenhouse gases in carbon dioxide equivalents (CO_2e). Emissions of gases other than CO_2 are translated into CO_2 equivalents based upon their relative ability to trap heat in the atmosphere using global warming potentials. Generally speaking, CO_2 tends to represent the largest mass of greenhouse gas emissions, but the other three major types of gases tend to have greater impact per mass of discharge. This report uses STAPPA/ALAPCO and ICLEI's Clean Air and Climate Protection Software (2003) developed by Torrie Smith Associates Inc. Details for this calculation are included in Appendix E. Software input values and detailed results are presented in Appendix F.

For this GHG inventory, the ESC has selected calendar year 2009 as the time period because it was the most recent year for which data were available and because its average temperature did not fluctuate substantially from the historical average, making it a reasonable basis for comparison. The geographic area considered is within the town boundaries, and sources of GHG emissions have been grouped into four main categories:

- Energy (electricity, natural gas, and heating oil)
- Transportation
- Water and wastewater
- Solid waste and recycling

Where information is available, the main categories have been subdivided into residential, industrial, and commercial subcategories. Each main category includes the GHG contribution of the town’s municipal operations. Municipal energy use and carbon emissions are addressed in greater detail in Section 3 of this report. For purposes of this report, “municipal” includes school facilities and operations, except where identified separately.

The emphasis of this study is to quantify GHG emissions resulting from the use of fossil fuels. It is assumed that CO_2 and methane emissions from natural sources and the decomposition of organic waste (e.g., yard waste, food scraps) are part of the natural carbon cycle and are not quantified.

2.1 Electricity and Heating Fuels

Energy consumption for electricity, natural gas, and heating oil end uses represents a significant source of GHG emissions in Stoughton that residents and facility operators can modify. It is important for the town to understand how energy is used by various end use groups if future GHG reduction efforts are to be effectively formulated and implemented.

Electricity

Electricity in southern New England is mostly generated by natural gas-fired power plants with additional generation from older coal-fired plants and the Pilgrim nuclear station. Hydropower from Canada represents the only significant renewable generation source. Electrical energy is currently the most GHG-intensive energy type relative to natural gas and heating oil. Based on the ICLEI software, the average carbon equivalent is 0.7350 lb CO_2 per generated kWh.

The majority of Stoughton lies within National Grid's service territory. There are a limited number of accounts along Bay Road on the border with Sharon that are served by NSTAR Electric. These NSTAR accounts were not included in this baseline study.

Figure 2.1.1
Distribution of Electricity Use (kWh)

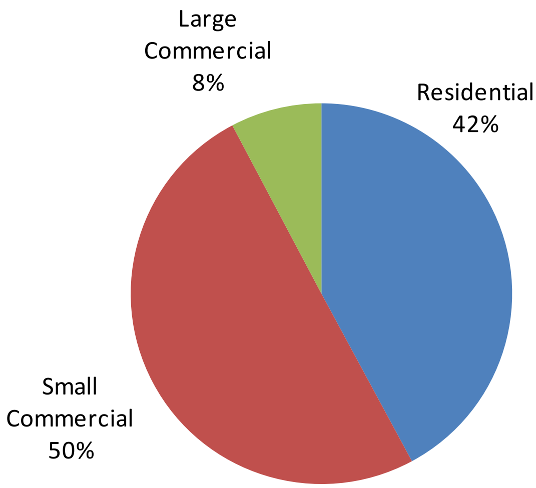
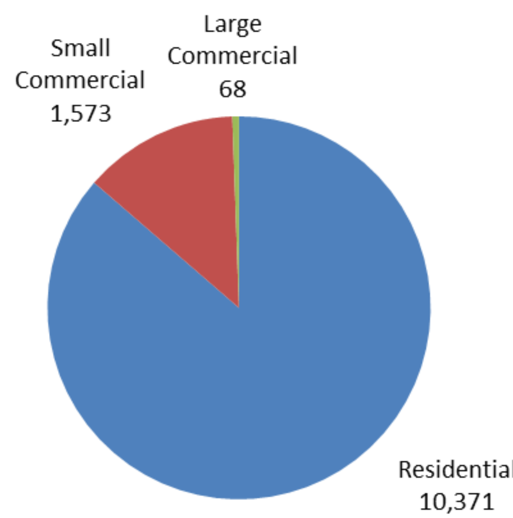


Figure 2.1.2
Number of Electrical Service Accounts



The ESC obtained aggregate electricity consumption data for calendar year 2009 from National Grid (see Figure 2.1.1 above). Consumption data were provided by type of account: Large Commercial, Small Commercial, Standard Residential, and Residential with Electric Heat. The utility provided the total number of accounts of each type as well (Figure 2.1.2) to allow the ESC to calculate the average energy use per end user. Raw data are included in Appendix D. Data for the two types of residential accounts were combined since the number of residential with electric heat accounts represented less than 1% of the total number of accounts.

Small commercial customers, defined as non-residential accounts having a peak power demand less than 200 kW, consume 50% of the electricity in Stoughton. Examples of these customers are office buildings, small retail stores, elementary schools, and town facilities. In 2009, the average small commercial customer used 60,800 kWh and had an annual average power demand of 6.94 kW.

Stoughton only has 68 large commercial electricity accounts (0.6% of the total), but these few accounts consume 8% of the electricity. A large commercial customer is one that has a peak power demand greater than 200 kW during the typical year. The IKEA store, the high school, and large supermarkets are in this customer group. The average large commercial customer used 218,300 kWh in 2009 and had an average power demand of 24.92 kW.

Residential customers represent the bulk of the accounts (86%) but only 42% of the electricity use. The average residential customer used 7,746 kWh and had an average annual power demand of 0.88 kW. The typical house in Massachusetts used 7,320 kWh per year in 2009 (13), thus Stoughton residents use slightly more (6%) electricity than the typical house in the Commonwealth. At an average billing rate of $0.1687 per kWh, the typical residence paid $1,307 for electricity. Assuming energy prices remain stable, a 10% reduction in electricity use by the average house would save each household $130 per year.

If Stoughton were to strive to reduce GHG emissions associated with electricity consumption, focusing on commercial customers is likely to yield a significant impact. National Grid has very good incentive programs in place to help commercial customers reduce their electricity consumption, and the town could help to publicize this resource.

Over the past three decades, the average commercial and residential electricity use per account has risen. With effective electricity conservation and efficiency efforts, this trend can be reversed, reducing GHG emissions and saving money for the town, its businesses, and its residents.

Natural Gas

Most natural gas used in New England arrives via pipelines originating in the US gulf states. Some gas is delivered in liquefied form via ocean vessel at a number of ports, including one in Everett, Massachusetts. Natural gas is a relatively clean fuel when compared to electricity. For the sake of comparison, one Btu of natural gas will generate 57% the amount of GHG emissions of one Btu of electricity. These emissions are typical of natural gas whether delivered via a street connection or from an on-site propane tank. This analysis focuses on gas use for customers with street connections; data for propane use could not be obtained by the ESC.

Columbia Gas (formerly Bay State Gas) is the primary natural gas supplier to Stoughton. ESC obtained aggregate gas consumption data and the number of customer accounts, see *Figure 2.1.3* and Figure 2.1.4 below. Customer types include commercial, residential with gas-fired heating systems, and residential with non-gas fired heating systems. An example of this third type of customer would be one that uses natural gas for cooking and water heating but fuel oil for space heating.

Most natural gas consumed in Stoughton is used by commercial and residential customers for space heating. As a result, colder weather conditions will impact consumption. Stoughton's weather conditions can be inferred from those of Norwood Memorial Airport, the location closest to Stoughton that formally collects data for the National Oceanographic and Atmospheric Association (NOAA). In 2009, Norwood Memorial Airport logged 6,433 HDD65 (heating degree days relative to 65°F). A typical year, based on weather data from 1991 to 2005, has 6,244 HDD65. Thus, 2009 was about 3% colder than a typical year. One would expect natural gas, propane, and heating oil use to be slightly lower during an average year.

Figure 2.1.3

Distribution of Natural Gas Use (therms)

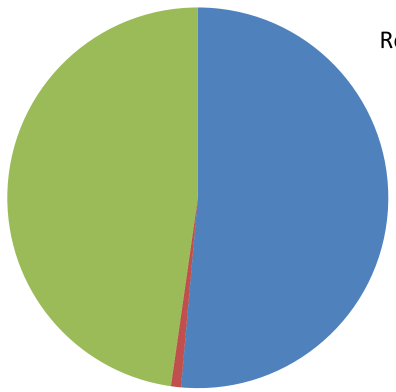
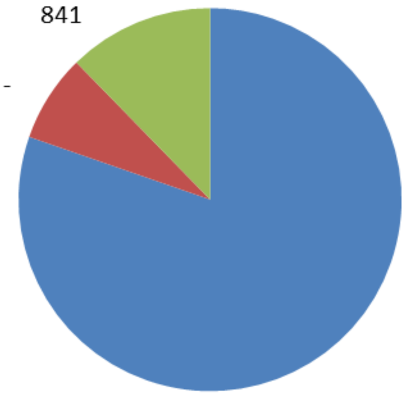


Figure 2.1.4

Number of Natural Gas Service Accounts



Commercial customers use 48% of the natural gas in town and represent 12% of the accounts. Most gas is used for heat to overcome building envelope thermal losses and ventilate air. Minor end uses are likely to include water heating for use in restrooms. Some large institutional customers, such as hospitals and medical offices, may use a considerable amount of gas for laundry and cooking. Food manufacturers and industrial operations may use large amounts of gas for specialized processes. The typical commercial gas account used 5,620 therms in 2009.

It is interesting to note that there are 841 commercial gas customer accounts but 1,641 commercial electric accounts and, as will be discussed below, 80 commercial properties using oil heat. This suggests that many commercial operations have multiple electricity accounts, or some may not use heating fuel, or they use an alternate fuel source such as propane.

Residential customers represent the majority of gas accounts (88%) but consume only 52% of the fuel. The customers that do not use gas for space heating (7% of all accounts) use only 1% of the total gas volume. The average non-heat customer uses 170 therms per year, and it can be assumed that this same amount of consumption is typical for water heating, laundry drying, and cooking in houses with gas heat. The average house with gas heat consumes 938 therms in total, 82% of which is likely used for space heating.

The average house in New England used 850 therms in 2009 according to the US Energy Information Administration (US EIA) (14). Thus, the typical residential customer in Stoughton uses around 10% more gas per year than the typical residential customer in New England. The US EIA estimates that new homes use 31.8% less gas than older homes. The fact that 83% of Stoughton's housing stock was constructed before 1980 (7) might explain the higher gas use.

Columbia Gas currently has very good incentive programs that encourage the installation of high performance heating equipment as part of new construction, end of life replacement, and retrofit projects. Incentive amounts vary depending on equipment capacity and the performance rating. Weather sealing and insulation incentives for residential customers are expected to remain very aggressive in the coming years. Minimization of infiltration (air entering and leaving the building through cracks and gaps) has a very large impact on overall energy performance. Insulation provides a secondary means of reducing heat loss but the benefit is much less significant than efforts to reduce uncontrolled airflow.

Additional gas savings can be achieved through the following changes, most of which qualify for incentives:

- Optimized ventilation controls
- Optimized equipment staging and burner controls
- Steam trap maintenance
- Piping and equipment insulation
- Automatic space temperature controls
- Reduced hot water use through efficient appliances and user choices

Fuel Oil

Fuel oil was at one time the most common space heating fuel in southeastern New England but has been replaced by natural gas and propane in many areas. This transition is being accelerated by the availability of cleaner burning, more efficient gas-fired heating systems. No. 2 heating oil releases approximately 34% more GHG emissions than natural gas on a Btu basis. Fuel oil is delivered to users in Stoughton via a number of small-scale suppliers. Given the multitude of delivery companies and the competitive nature of the fuel oil market, the ESC was unable to obtain consumption data specific to the town. Town Assessor's records indicate that that there are 3,650 residential properties and 80 commercial properties that use oil for heating. The actual numbers may be slightly lower due to the ongoing conversion of customers away from oil heat to natural gas and propane.

Annual oil consumption estimates can be generated based on the typical space heating requirement estimated for the typical natural gas customer. The heat contents of natural gas (100 kBtu per therm) and No. 2 heating oil (140 kBtu per gallon) are used to translate heat requirements to equivalent gallons of oil. Stoughton's oil use is estimated using the following expressions:

Typical residential oil use, gallons = 769 therms * (100 kBtu/therm ÷ 140 kBtu/gallon)

= 549 gallons per residential customer

Typical commercial oil use, gallons = 5,620 therms * (100 kBtu/therm ÷ 140 kBtu/gallon)

= 4,014 gallons per commercial customer

Town oil use, gallons = (3,650 residential * 549 gallons) + (80 commercial * 4,014 gallons)

= 2,324,970 gallons

Residential oil use is likely to be underestimated since older, less efficient homes are likely to have oil heat while newer homes probably use natural gas or propane. The estimate for commercial oil use may be slightly high since the heat requirement is based on gas use, and most large commercial operations have converted to gas heat or have dual-fuel burners that are typically run with gas due to recent pricing trends. Commercial oil customers may have smaller heat requirements than the typical gas customer.

Available data do not provide a firm basis for determining the effectiveness of energy efficiency and conservation efforts. The ESC recognizes the challenge of quantifying fuel consumption for fuels that are stored on-site and hopes to use a more robust methodology for future versions of this study. One approach may be to interview 5% of the residential fuel oil users to determine their annual oil consumption and to speak with 25% of the commercial oil customers. The sampling methodology can be adjusted, but the sample size should be selected based on the typical variability of heating loads. Commercial operations can vary significantly in size and heating loads whereas residential use is fairly closely linked to house size.

Disposal of waste oil through combustion for space heating has not been quantified. It is estimated that this source of oil heat is insignificant relative to the overall GHG emissions of the town.

Renewable Energy Systems

The ESC recognizes that a small number of rooftop solar photovoltaic and solar hot water systems have been installed and are operating in Stoughton. However, due to the anticipated relatively small impact these systems currently have on the total GHG production in Stoughton, the ESC has not attempted to quantify the energy produced or GHG emissions conserved by these systems.

State and federal incentive programs and the market for solar renewable energy credits (SRECs) have reduced the payback period for small photovoltaic systems to be in the range of 5 to 7 years. Stoughton residents with an interest in solar energy can receive free site audits from licensed installers to help determine whether installation of a system is an economically sound decision for their site and needs. Tax incentives are also available for solar hot water installations. The ESC sees a large potential for cost effective implementation of solar technologies in Stoughton.

Many Stoughton residents burn wood as a secondary fuel source, and a small number heat primarily with wood. The ESC does not have access to data at this time to quantify the volume of wood burned for heat. It is likely that the majority of heat generated in town is produced from natural gas and heating oil.

2.2 Transportation

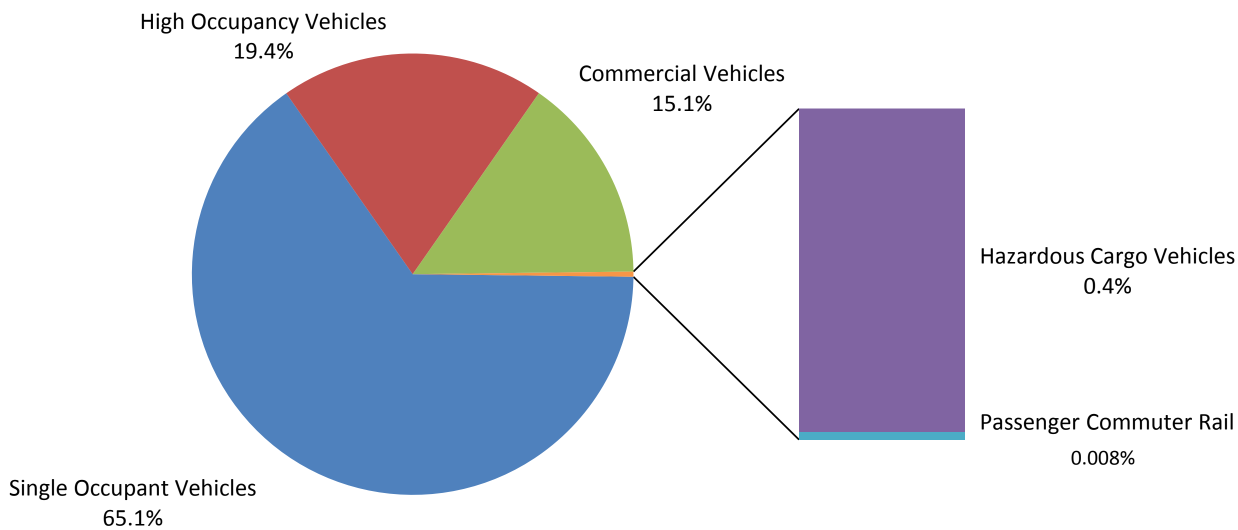
According to the US EPA, transportation sources accounted for 29% of total US GHG emissions in 2006. Transportation is the fastest-growing source of GHG emissions in the US, accounting for 47% of the net increase in total US emissions since 1990. Transportation is also the largest end-use source of CO_2, which is the most prevalent greenhouse gas. These estimates do not include emissions from additional lifecycle processes, such as the extraction and refining of fuel and the manufacture of vehicles, which are also a significant source of domestic and international GHG emissions (15).

Looking forward, transportation GHG emissions are forecast to continue increasing rapidly, reflecting the anticipated impact of factors such as economic growth, increased movement of freight by trucks and aircraft, and continued growth in personal travel. According to the US Department of Energy (DOE), transportation energy use is expected to increase 48% between 2003 and 2025, despite modest improvements in the efficiency of vehicle engines. It is expected that transportation GHG emissions will follow the rise in transportation energy consumption (16).

The ESC has chosen to track GHG emissions relating to transportation based upon all vehicles passing through the town. This is a standard approach used by other communities and the data was available from the state to support this analysis. An alternate approach is to calculate the GHG emissions generated by vehicles that are owned and garaged within Stoughton. Major transportation corridors, such as Routes 24, 138, 139, and 27, represent most vehicle miles traveled in town.

According to the Central Transportation Planning Staff (CTPS), in 2009, the average daily transportation GHG emissions within Stoughton were 372,180 kilograms (820,515 pounds). This equates to 149,744 tons of CO_2 per year. This includes emissions from single occupancy vehicles, high occupancy vehicles (buses), commercial vehicles, hazardous cargo vehicles, and the portion of the commuter rail running within Stoughton. Tabular data provided by CTPS is included Appendix D and is presented below.

Figure 2.2.1
Number of Vehicle Miles Traveled within Stoughton's Borders



The total transportation mileage estimated within Stoughton is 666,670 miles per weekday and 243.33 million miles per year. At an estimated average mileage of 16.4 miles per gallon and an average fuel cost of $2.75 per gallon, approximately $40.8 million was spent on transportation fuel in Stoughton in 2009.

CTPS did not provide a number for the typical occupancy on high occupancy vehicles or commuter trains. High occupancy vehicles include Brockton transit buses that serve routes in Stoughton. An interesting plot to include in future reports is the amount of GHG emissions per person per mile traveled.

The transportation GHG emissions baseline value can be improved upon in a number of ways, but the town and the ESC do not have a significant ability to impact the vehicle miles passing through Stoughton. Improvements in average fuel efficiency, a general trend towards car pooling, and increased use of the train system could result in lower GHG emissions within Stoughton's borders.

The data provided by CTPS only reflects transit on main highways and does not account for traffic on side roads. The CTPS modeling software is focused on capturing GHG emissions and vehicle miles traveled, and it is their position that traffic on minor streets is not a major contributor of vehicle miles traveled.

Had the ESC generated the baseline value from total miles traveled by cars garaged in Stoughton, future versions of this study would be better able to determine the impacts of outreach efforts to minimize single-occupant travel and increase use of public transportation. This alternate approach would probably require input from the Commonwealth's vehicle inspection process to determine the aggregate number of miles traveled, and this data is not available at this time.

The Town of Stoughton could encourage residents to purchase more efficient vehicles by offering a vehicle excise tax waiver for a certain number of years. Qualifying vehicles would need to have a rated fuel efficiency of greater than a benchmark such as 40 miles per gallon. This benchmark could be increased as the market evolves.

2.3 Water Use and Wastewater Disposal

This section describes the overall water use and wastewater disposal characteristics of the town. The GHG impacts of the two systems are discussed in greater detail in Chapter 3 as part of municipal energy use.

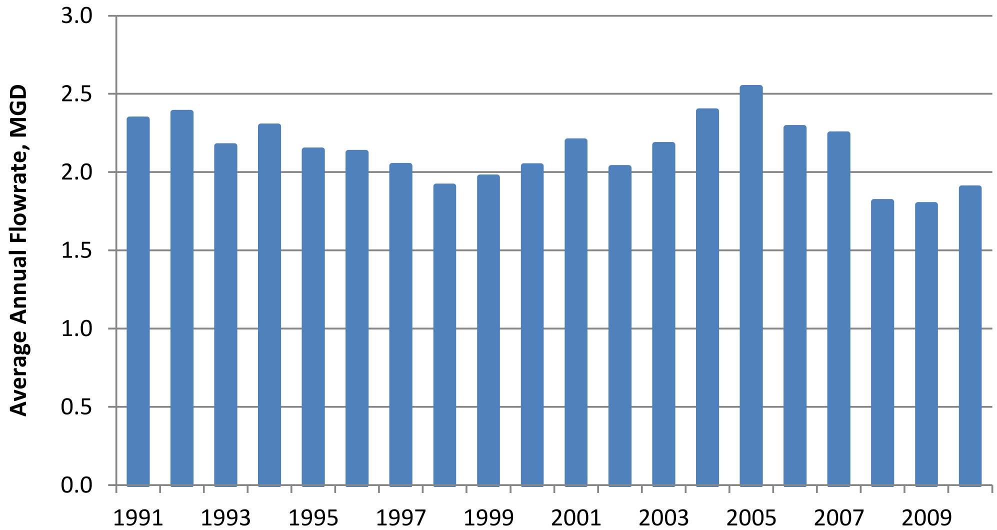
Water Supply

While Massachusetts receives a seemingly large amount of precipitation throughout the typical year, urban expansion and residential development in rural areas creates fresh water demands that are beginning to outstretch local resources. Stoughton began to experience water shortages in the 1980s with increased residential construction, and the town invested in new wells and storage capacity. Shortages were once again a problem in the mid-1990s when extraction limits were placed on town wells. The town began to explore connection to the Metropolitan Water Resource Authority (MWRA) water supply in the late 1990s, and a concerted water conservation effort was implemented to satisfy a prerequisite for the interconnection agreement (17). The town has been receiving MWRA water since late 2003.

The town water supply system provides water service and fire protection to serve most of the town residences and commercial properties. The system includes seven ground water wells with treatment at each well station, four water storage tanks with a combined capacity of 14 million gallons, and 147.6 miles of water main. Emergency pump stations are in place to obtain water from Brockton, Easton, and Sharon (18). A large fraction of the town's water (typically around 30%) is provided by the MWRA through an interconnection at the Stoughton/Canton town line on Island Street. Historic water production volumes for the municipal water supply system are illustrated in Figure 2.3.1 below.

Figure 2.3.1

Historic Average Daily Water Production



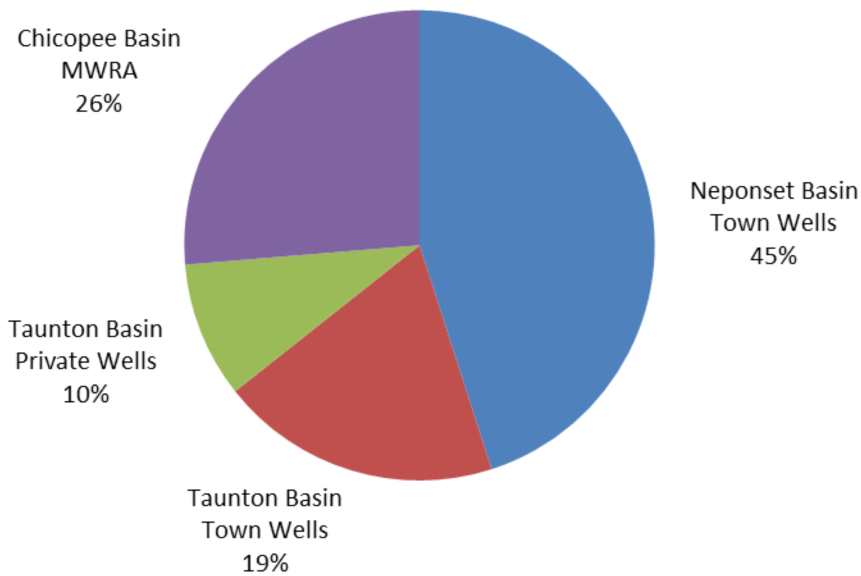
The total volume of water than can be extracted from town wells is regulated by the Massachusetts Department of Environmental Protection (MA DEP). Permitted extraction in 2009 were 1.21 millions of gallons per day (MGD) from the Boston Harbor Basin and 1.27 MGD from the Taunton Basin for a total authorized daily volume of 2.48 MGD (20). This permitted extraction rate is greater than the 2009 average daily water use. In 2009, the town pumped an average of 1.27 MGD from its wells and supplied an overall average daily volume of 1.81 MGD to the system.

Recent improvements to the town wells may reduce reliance on the MWRA source. The town purchases MWRA water at a rate of approximately $2,400 per million gallons while operation of the pump stations costs $178 per million gallons (excluding chemical treatment and maintenance costs). Increased pumping from the town wells is likely to save the town money. Reduced water consumption in town could lead to reduced MWRA purchases and thereby save additional money.

The Town of Stoughton receives water from three resources: the Neponset River Basin, the Taunton River Basin, and the MWRA water supply originating in the Chicopee Basin in central Massachusetts. As illustrated in Figure 2.3.2, most water used in town comes from the Neponset River watershed. It is assumed that all privately owned wells in town are located in the Taunton River watershed. Map 4 in Appendix B illustrates the location of the watershed boundary.

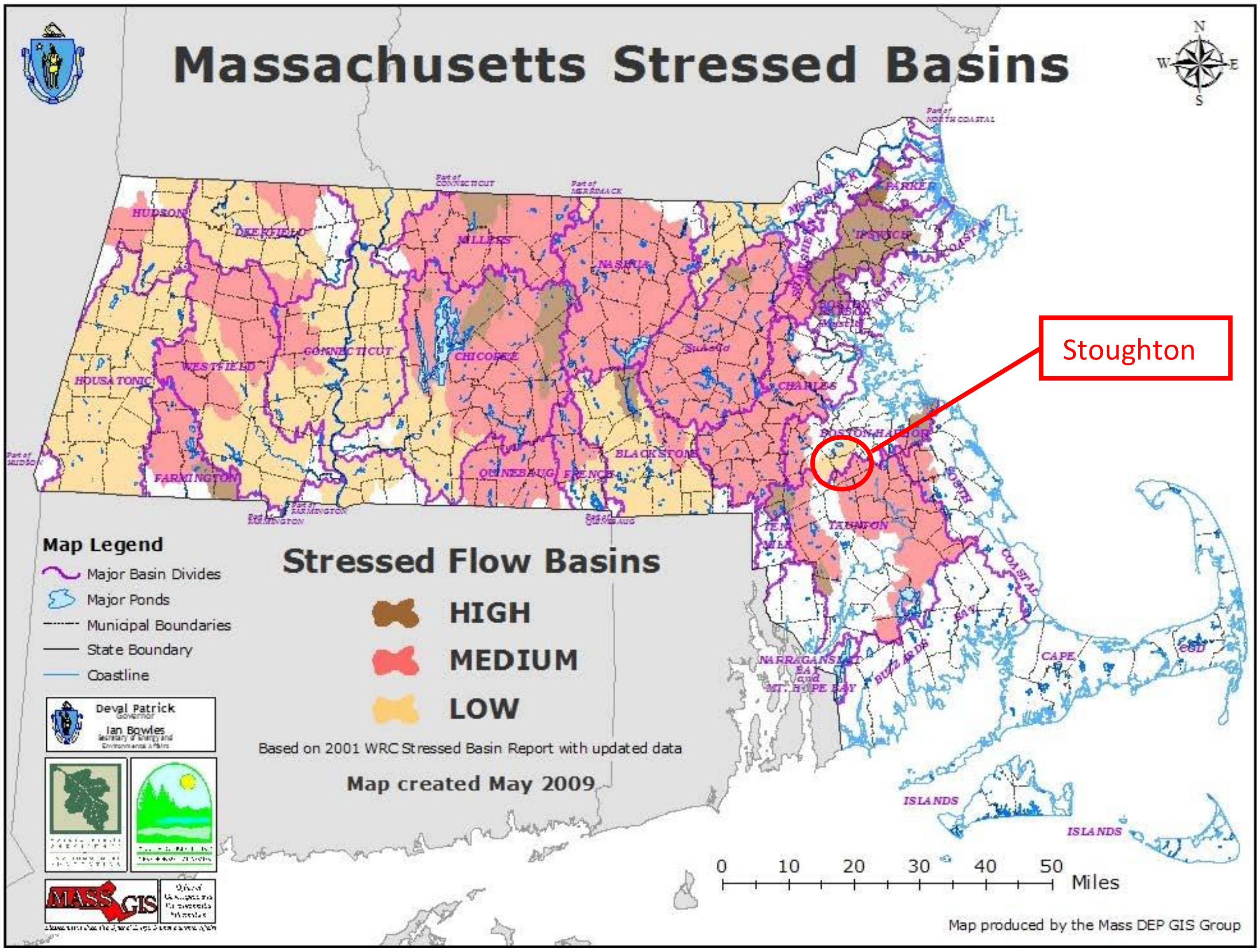
As shown in Figure 2.3.3 below, the Neponset River watershed is part of the Boston Harbor Basin and is rated as having a low stress level within Stoughton's town boundary. However, there is published evidence that the East Branch of the Neponset River in Stoughton may be impacted by groundwater extraction. The Taunton River watershed is considered to be medium stressed within Stoughton. The Chicopee Basin is rated as having low, medium, and high stress in the areas bordering the Quabbin Reservoir. Therefore, water conservation efforts will not only save the town money but also reduce stress on the Neponset River, the Taunton River, and the Chicopee Basin resources.

Figure 2.3.2
Water Supply by Resource Category



Properties located generally in the southwest portion of town near Ames Long Pond are reliant upon privately owned borehole wells. The town does not currently know how many properties have their own wells, and withdrawal volumes from private wells are not reported to the MA DEP. It is assumed that 13% of the total water use in town originates from privately owned wells and that these properties use the same amount of water, on average, as residences connected to town water. The 13% figure is estimated based on difference between total population in 2000 and the number of residents provided with town water according to the 2009 Public Water Supply Annual Statistical Report (ASR), which uses Year 2000 census data. The study does not account for withdrawals from private irrigation wells.

Figure 2.3.3



The Massachusetts Water Resources Commission (WRC) issued a policy statement on December 13, 2007, titled *Policy for Developing Water Needs Forecasts for Public Water Suppliers and Communities and Methodology for Implementation* (21). Item II.D.2 on Page 4 requires the following:

a. Unaccounted for water should not exceed 15% over a 3-year period.
b. All systems having unaccounted for water exceeding 10% must have a program in place to reduce unaccounted for water to 10% or less as soon as practicable or as required by permit.
c. Residential water use should not exceed an average of 80 gallons per capita per day (rgpcd) in the most recent 3-year period.
d. All systems that have residential water use exceeding 65 rgpcd must have a program in place to reduce residential water use to 65 rgpcd or less as soon as practicable or as required by permit.

Stoughton's unaccounted-for water (UAW) is reported to have been 8.0% in 2009 (22). This value is calculated based on the difference between pumped volumes/purchased MWRA volumes and the total volume recorded by town meter readings. While the town appears to be in compliance with the MWC policy cited above, further reductions in lost flow will reduce the amount of pumping energy required at town-owned and MWRA well stations, chemicals required for treatment, and purchase charges from the MWRA.

In 2009, the reported residential per capita water use to MADEP was 52.4 gallons per day per capita (rgpcd) (22). According to the data from the 2009 Public Water Supply ASR, 69% of the town supplied water flow was for residential use. Other water users include business and commercial facilities, industrial facilities, and municipal and institutional facilities. Municipal water uses for fire protection and training, hydrant and water main flushing, sewer system flushing, and street cleaning are included in a category called Confidently Estimated Municipal Use (CEMU). The distribution of water use is illustrated in Figure 2.3.4 below. The distribution of the number of water accounts is presented in Figure 2.3.5 and the average daily water use per account is illustrated in Figure 2.3.6 below.

The residential daily water use figure (52.4 gpcd) is lower than the MWC action levels of 80 rgpcd and 65 rgpcd cited above for implementation of water conservation programs. There do not appear to be requirements for water efficiency programs for the industrial and commercial sectors, and these sectors may present opportunities for water use reduction given the relatively low residential per capita use. Water use permits for large customers were originally issued in the 1990s and are due to be renewed within the next 2 years.

When private wells are taken into consideration, the total water extraction rate associated with Stoughton's use in 2009 is estimated to be 2.081 MGD, or 76.6 gpcd. This is the baseline that will be used going forward. Note that the gallons per capita per day value includes all flows for the entire town and the entire population. Reductions in system losses and reduced water consumption will reduce these values.

Figure 2.3.4
Water Consumption by End Use Group (gpcd)

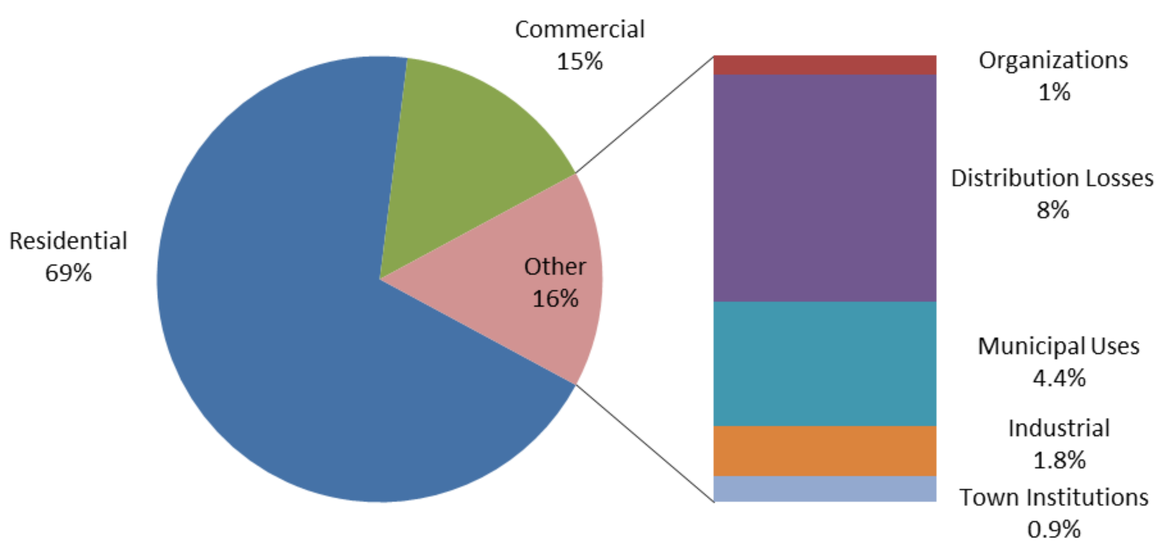


Figure 2.3.5
Distribution of Water Service Accounts

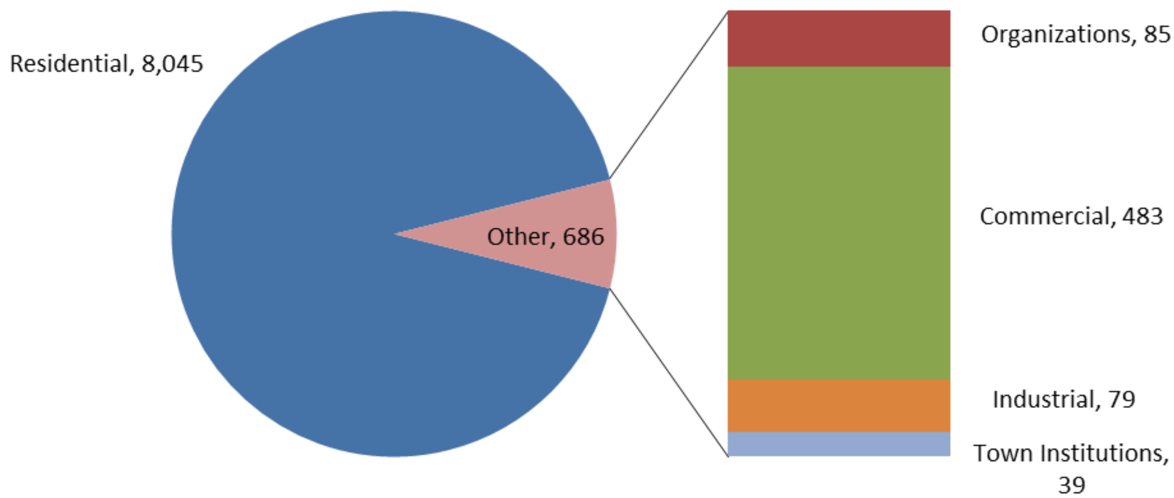
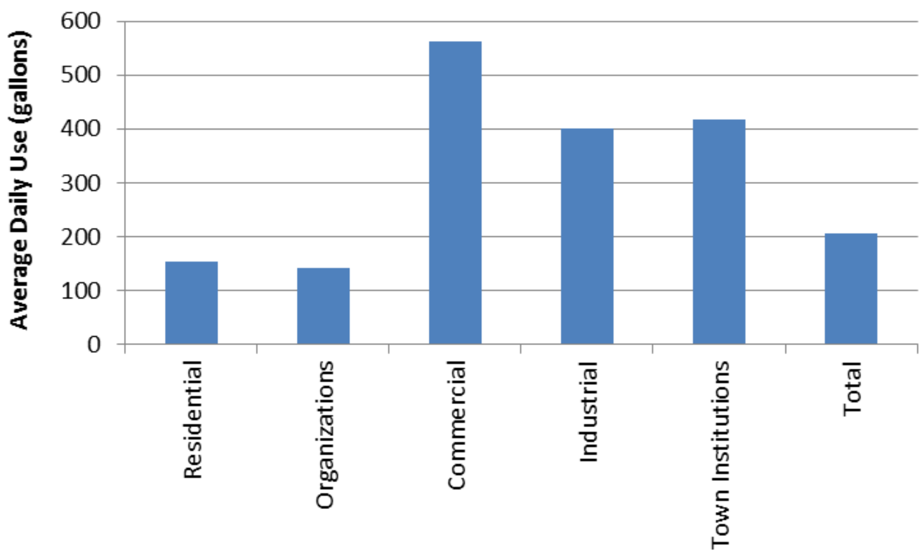


Figure 2.3.6
Average Daily Water Use per Account



Wastewater Disposal

Wastewater disposal regulations continue to become stricter over time as the MA DEP and US EPA strive to improve the health of our nation's waterways and protect ground water resources. Centralized wastewater systems require a significant amount of energy to operate and can represent a significant portion of municipal operating budgets.

Municipal wastewater (i.e., domestic sewage) generated in Stoughton is either disposed of via sewer and ultimately treated at the MWRA Deer Island Wastewater Treatment Plant (67% of domestic sewage) or disposed of and treated by onsite septic systems (33% of domestic sewage). In addition to the sewered domestic sewage flow, there are two other water flows that enter the Stoughton sewer system and thereby become part of the wastewater flow logged by MWRA: inflow and infiltration (I/I).

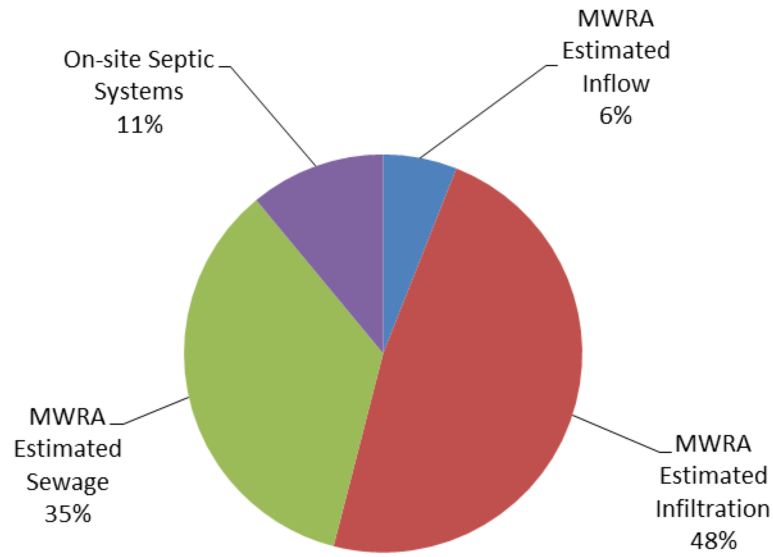
Inflow is an intermittent rainwater or surface water flow that occurs during wet weather events. Inflow can enter the sewer system through illicit connections to the sanitary sewers from roof leaders, drains (e.g., cellar, yard, and area), sump pumps, drains from swampy areas, cross-connections, or improperly piped catch basins. The duration and flow magnitude of wet weather inflow is variable because it is dependent on the duration and magnitude of a particular storm. Inflow volumes can be quite large during a short time period and can cause sewer backups and other negative events if the sewer system is overwhelmed. However, since inflow is an intermittent flow, it is a smaller contributor to total annual flow in the sewer system.

Infiltration is flow of groundwater into the sewer system via cracked pipes, broken or leaky joints, leaky manholes, or other defects in the system and differs from inflow because it is continuous in nature. Infiltration can occur in both public and private parts of the sewer system. Although infiltration is continuous, seasonal flow variations do occur because the groundwater table varies with season. For example, the highest infiltration rates are usually recorded in the spring and mirror increases in the groundwater table via snowmelts. In general, the annual infiltration flow rate is very large compared to the annual inflow rate.

MWRA logs the wastewater flows from all the towns that contribute to the flow to the Deer Island Treatment Plant and then estimates the relative contribution of domestic sewage, inflow, and infiltration. Figure 2.3.7 below illustrates the relative distribution of waste sources for 2009. Each wastewater source is also labeled with its ultimate treatment point (MWRA Deer Island Treatment Plant or onsite septic in either the Neponset or Taunton River watershed). Flow volumes (inflow, infiltration, and sewage) treated by the MWRA are taken from MWRA reports for 2009. On-site treatment flows are estimated based on the previously published 52.4 rgpcd water consumption for Stoughton in 2009.

Determining the relative contributions of the three different flows in a wastewater system can be complicated, but methods for estimating relative flows exist. For 2009, the MWRA data describe Stoughton as having approximately 72 miles of sewer mains with a total sewered population of 17,933 people (23). The average 2009 total wastewater discharge rate was 3.83 MGD per MWRA records. The 2009 wastewater data was partitioned by MWRA as follows: the average daily infiltration rate was 2.07 MGD, the average inflow rate was 0.26 MGD, and the sanitary flow was 1.50 MGD. Therefore, in 2009, I/I represented 61% of the wastewater flow according to MWRA records.

Figure 2.3.7
Estimated 2009 Wastewater Flows by Source



The MWRA average sanitary per capita wastewater flow rate for the sewered population was reported as 84 gpcd including all flows to the system. In 2009, Stoughton was reported to have an I/I inflow rate of 3,752 gallons per day per inch-diameter-mile (GPD/IDM) and an infiltration rate of 3,333 GPD/IDM. To contextualize this latter value for infiltration, although the MA DEP does not have a specific definition of what rate constitutes excessive infiltration, its DEP Guidelines for Performing I/I Analyses and Sewer System Evaluation Survey makes the follow recommendation: "an extensive manhole inspection and flow isolation program can be recommended for all subsystems exhibiting an infiltration rate equal to or great than 4,000 GPD/IDM. Further work on subsystems with a lesser rate can be justified on a case-by-case basis." (25)

The town is nearing the end of a 10-year program to identify and remediate I/I flows. Inflow is considered essentially 100% remediable since it represents illegal connections to the sewer system, and once these connections are identified, the inflow can be stopped. Infiltration remediation is a mitigation process, since infiltration flows tend to migrate from repaired areas to other inlet points via a process called groundwater migration. Addressing a particular infiltration project also involves a cost effectiveness analysis (a determination of whether it is more costly to remediate the infiltration point than to transport and treat the infiltration) and a value effectiveness analysis (a determination that a project provides significant technical, health, or environmental benefits even though it is not cost effective).

The control of I/I is important because it can exacerbate groundwater and water supply depletion, deplete groundwater that may serve to dilute pollutants in contiguous surface water supplies, and put excess demands on both the carrying capacity of the sewer system and the wastewater treatment facility that serves the sewer system. There are costs associated with sending I/I flows to the Deer Island Treatment Plant. For example, the town pays the MWRA approximately $3,600 per million gallons of flow regardless of whether it is infiltration or wastewater. Municipalities are largely responsible for maintaining their sewer systems although state funds are available for remediation. The town has already removed approximately 1.0 MGD worth of infiltration over the past decade through ongoing line maintenance and upgrade projects financed through a $2,696,900 MWRA grant. At the beginning of FY10, there was still $498,500 available to the town for continued infiltration reduction efforts.

The 2009 average daily flow of 3.83 MGD has an associated annual cost of around $5,033,000. The infiltration reduction efforts to date (~1.0 MGD reduction) have saved the town $1.31 million - equivalent to a 2.0-year payback on the MWRA's assistance grant and representing a 21% reduction in annual fees. Further reductions in MWRA flows through infiltration reduction or water conservation programs can save the town considerable money in MWRA fees. Reduced lift station energy use is an added benefit that is discussed in the next chapter.

The GHG impacts of reducing infiltration are primarily experienced at Deer Island where every million gallon of wastewater handled produces 0.64 tons of CO_2. At the average infiltration rate reported by MWRA for the town of 2.12 MGD for the 2007-2009 time period, approximately 490 tons of CO_2 emissions are generated per year. For comparison, these emissions are greater than the emissions associated with operation of the town's streetlights. This is a minimum estimate of emissions, and the value increases when operation of the town's pump stations and the MWRA lift stations between Stoughton and Deer Island are taken into account.

The baseline wastewater flowrate calculated for 2009 is 84.0 gpcd. Future reductions in I/I and municipal water consumption are likely to reduce this number.

2.4 Solid Waste Management and Recycling

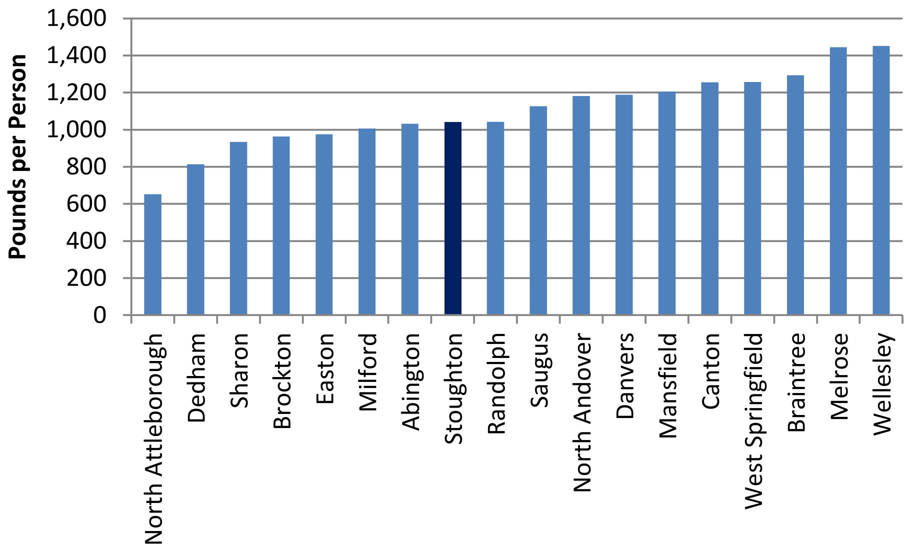
Solid waste handling has evolved into an essential service provided by communities to promote public health and economic vigor. Most municipalities either provide residential waste collection, contract with outside haulers to collect and transport waste, or allow haulers to contract directly with individual residences. The Massachusetts Department of Environmental Protection (MA DEP) monitors solid waste generation rates to ensure resources exist for the safe disposal of solid waste and other non-hazardous debris. Figure 2.4.1 below illustrates the 2008 solid waste volume on a per-person basis for Stoughton, neighboring municipalities, and communities having similar population sizes as Stoughton. Note that Wellesley and Melrose accept commercial recyclables deposited at their central collection facilities, which are likely to be open to receive materials more than one day per week.

The management of solid waste impacts greenhouse gas emissions and climate change in several ways:

- Waste deposited in landfills produces methane (CH_4), a greenhouse gas 21 times more potent than CO_2.
- Incinerating waste produces carbon dioxide and other greenhouse gas byproducts.
- Collecting and transporting waste to landfills and incinerators uses fossil fuels, releasing greenhouse gas emissions into the atmosphere.
- When materials are discarded instead of recycled or reused, new products are required to replace them. The processes involved in extracting raw materials, manufacturing new products, and transporting them to market all require fossil fuels.

Waste prevention presents the most attractive option for reducing GHG emissions from the waste stream. Less waste is typically associated with reduced disposable packaging of retail goods, the adoption of business practices that do not generate paper waste, and responsible on-site composting of vegetable matter. Less waste production has GHG impacts throughout the supply chain through less processing of raw materials, less transportation weight (both pre- and post-consumer), and ultimately less air pollution through burial or incineration. Waste prevention tends to reduce costs for all parts of the production and disposal stream (26).

Figure 2.4.1
Per-Person Solid Waste Generation



Recycling presents the next best alternative to waste prevention. Generally, manufacturing products from recycled materials uses less energy than manufacturing from virgin materials due to the reduced need to extract, transport, and process raw materials. Paper recycling has a dual, positive impact on reducing GHG emissions because it reduces not only waste but also the demand for trees. Since trees remove CO_2 from the atmosphere and store it, preserving their numbers rather than cutting them down to make more paper helps reduce GHG emissions.

As noted earlier, the 2008 Massachusetts Global Warming Solutions Act has committed the state to an 80% reduction in GHG emissions from 1990 levels by 2050, and in December 2010 the state set an ambitious target of 25% reductions by 2020. To help achieve these targets, the draft Massachusetts 2010-2020 Solid Waste Master Plan: Pathway to Zero Waste, released by the MA DEP in July 2010, focuses on strategies to dramatically decrease waste generation and increase recycling and reuse of materials that would otherwise go into the waste stream. The MA DEP and has established a statewide goal of reducing solid waste disposal by 30% from 2008 levels by 2020 (27).

<u>DPW Collected Materials</u>

The discussion that follows focuses on residential and municipal solid waste volumes. Inadequate information is available at this time to include a discussion of commercial and industrial waste volumes. The data presented in this section have been provided by the Stoughton Department of Public Works (DPW) and the MA DEP.

The Stoughton DPW provides weekly residential curbside solid waste collection to residential buildings of three or fewer family units. Dumpsters are used for waste disposal at municipal buildings (not including schools), and the DPW collects this waste on a weekly basis as well. The DPW does not provide waste collection or disposal services to multiple family residential buildings with more than three units or to commercial or industrial facilities. Owners of these buildings are responsible for arranging for their own services with private waste haulers. The Stoughton Public Schools are responsible for their own waste collection and disposal and maintain contracts with private haulers for this purpose.

Stoughton has contracted with SEMASS/Covanta since 1985 to accept the town's residential and municipal solid waste. The waste is incinerated at the company's Rochester facility. The contract, recently extended to 2030, calls for an annual minimum combined waste and recycling tonnage commitment of 9,000 tons from the town. The agreement is structured so that if the total recycling tonnage increases but the solid waste tonnage goes down, the town is not penalized so long as it meets the minimum combined annual tonnage target.

The DPW has provided curbside recycling services to residential buildings of three or fewer family units since 1986. It does not collect recyclables at municipal buildings. Larger residential buildings and commercial and industrial facilities are served by private haulers, who are required by the MA DEP to divert recyclables from the waste stream. Residential recyclables collections occur twice a month. The following materials may be recycled curbside:

- Commingled materials (glass bottles, plastics #1-7, tin and aluminum cans, aluminum foil)
- Newspaper, brown bags, magazines, phone books, inserts (these paper recyclables must be separated from commingled materials)
- The DPW also collects Christmas trees curbside during the month of January at the residences it services.

In addition to residential curbside recycling, the town maintains a Transfer Station, open to residents who pay for sanitation services and have their trash collected by the DPW. The station is open Saturdays and accepts all the same materials recycled and collected curbside as well as the following materials:

- Corrugated cardboard
- Large metal household appliances: stoves, dryers, dishwashers, microwaves, refrigerators and freezers (with doors removed), lawnmowers (with gas removed)
- TVs and computer monitors
- Batteries
- Leaves and grass clippings for composting

The Christmas trees collected curbside are taken to the Transfer Station for composting as well.

Since October 2009 the DPW has been sending its curbside and Transfer Station recycling to Allied Waste Services' Brockton Recycling Center. Rebates for recyclables are subject to market fluctuations, but current contract terms call for rebates on newspaper and cardboard, thus reducing the town's overall waste management costs.

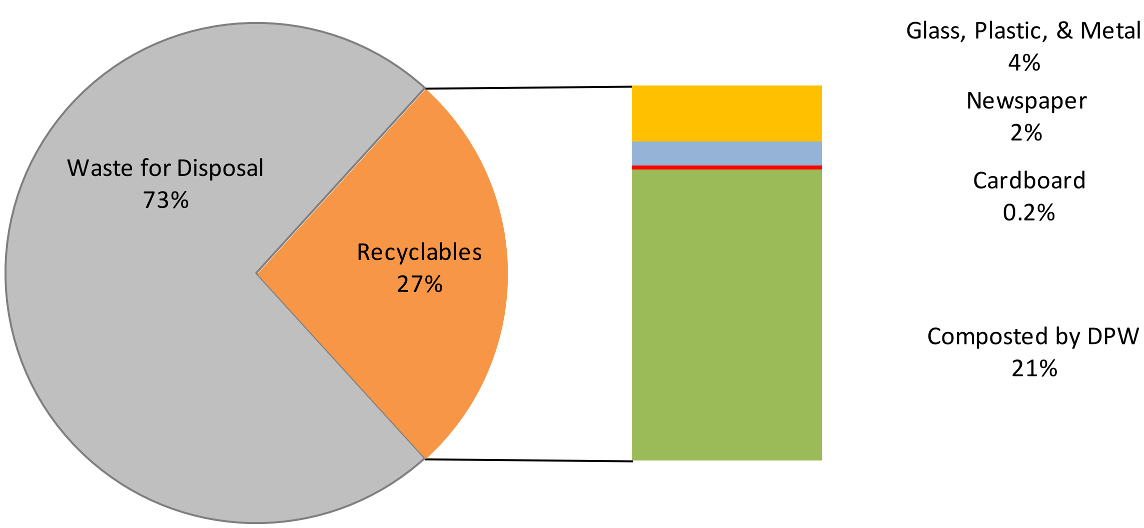
Stoughton's residential recycling rate, as reported by the MA DEP, ranged from 25% to 32% between 1997 and 2008. These rates are based on data provided by cities and towns on residential waste collection, recycling, composting, and hazardous waste collection, and include MA DEP estimates on unreported residential data for larger multiple-family dwellings. Stoughton's 2008 recycling rate was reported at 26%. The MA DEP stopped requiring municipalities to provide this information after 2008.

Since the DPW does not provide services to larger multiple family residential buildings or commercial or industrial facilities, it maintains no data on waste or recycling tonnage at these facilities. Before 2009, the MA DEP estimated unreported residential data for each municipality but maintains no data breakdown by municipality on commercial or industrial solid waste or recycling tonnage.

The DPW provided 2009 data on residential and municipal solid waste collection, and 2008 figures were used to estimate the unreported residential tonnage as well as the composted leaves, grass clippings, and Christmas trees. Based on these figures, in 2009, Stoughton disposed of 9,691 tons of waste. It composted 2,724 tons of yard waste and Christmas trees, and it recycled 527 tons of commingled materials (glass, plastic, metal), 224 tons of newspaper, and 22 tons of cardboard. This resulted in a recycling rate of 27% for calendar year 2009, as shown in Figure 2.4.2 below. Composted yard waste and Christmas trees, at an estimated 2,724 tons, represented 21% of all waste produced and 78% of the material Stoughton diverted from the waste stream. Non-compostable recyclables (glass, plastic, metal, newspaper, and cardboard), at 773 tons, accounted for just 6% of all waste produced and 22% of the material diverted from the waste stream.

The average person in Stoughton lives in a single-family house and generates 1,041 pounds of solid waste each year. This waste is transported to an incinerator where it is burned to generate electricity. Each resident's annual trash contributes 161 pounds of carbon equivalent. The typical household recycles a relatively small fraction of non-compostable waste that is generated: 8% by weight. This is equivalent to 73 lbs of recycled paper, cans, bottles, and cardboard out of an annual non-compostable trash weight of 839 lbs. Given apparently low participation in the voluntary recycling program, it seems likely that a concerted recycling and waste prevention education effort could improve Stoughton's recycling rate and reduce waste tonnage.

Figure 2.4.2
Residential Waste Production and Recycling Rates (Tons)



The Stoughton Sanitation Department consumed 25,560 gallons of diesel fuel in 2009 collecting residential solid waste. The trash is then transported by truck 31 miles to SEMASS Covanta in Wareham where it is incinerated to generate electricity. Fuel consumed by these trucks contributes to the town's carbon footprint.

Figure 2.4.3 shows a comparison of 2008 solid waste and recycling data for Stoughton, neighboring communities, and MA communities similar in population size to Stoughton. Stoughton has the lowest recycling rate of the communities included in this analysis. When collected compostable materials are included, Stoughton diverted a larger portion of the waste stream relative to several of the communities (see Figure 2.4.4). The US EPA reports that the 2009 US municipal diversion rate is 33.8% (28). Stoughton's diversion rate of 27%, including yard waste, is significantly below the national average. These results suggest that Stoughton may be able to improve participation in recycling programs through increased public education and outreach, and by allowing businesses to deposit recyclables at the transfer station.

Stoughton's Fire Department issues burning permits to residents for the period between January 15 to May 1. Permit holders burn a large amount of woody debris generated from tree trimming, cleanup of winter fells, and garden preparation. Provision of these permits may divert an unspecified volume of material from the waste stream, although it is unclear how much of the burned debris would otherwise be cut and bundled in a manner required for municipal pickup.

Some town residents compost some or all of their food waste, and this decreases the volume of waste trucked out of town. The ESC does not have access to data that quantify the volume of composted waste in the typical household. Ideally, the majority of residents would compost food waste. The town provides backyard composting bins for sale to residents, but there may be opportunities for increased public outreach in this area. Future versions of this study could attempt to quantify this impact.

Figure 2.4.3
Stoughton Recycling Rate Relative to Other Communities

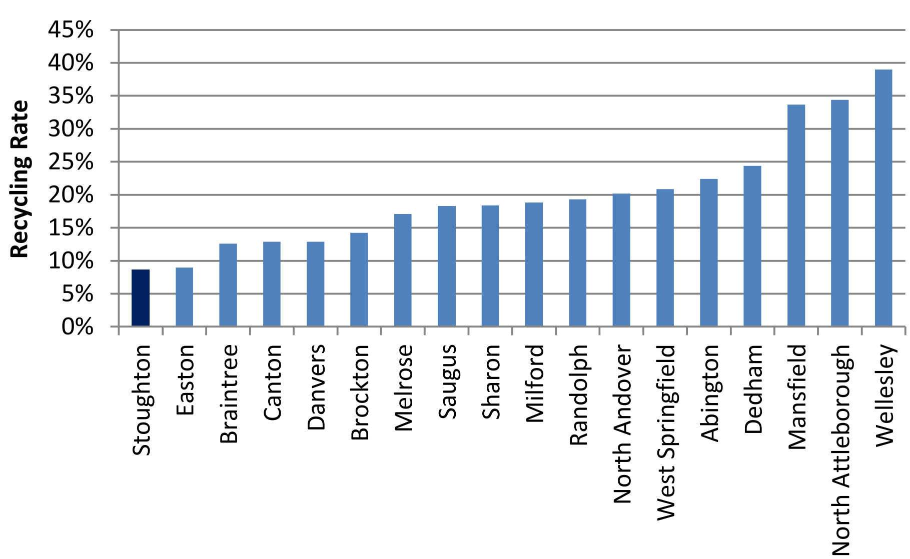
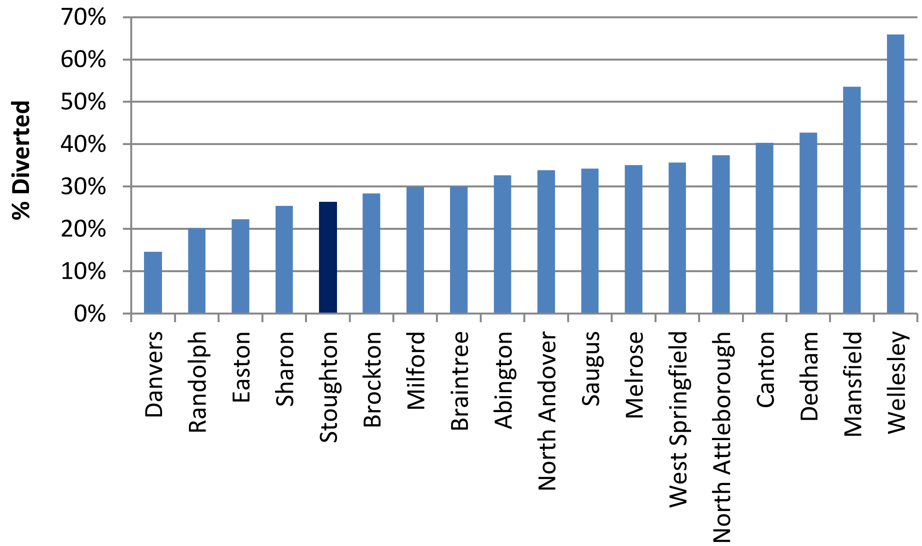


Figure 2.4.4
Stoughton Diversion Rate Relative to Other Communities

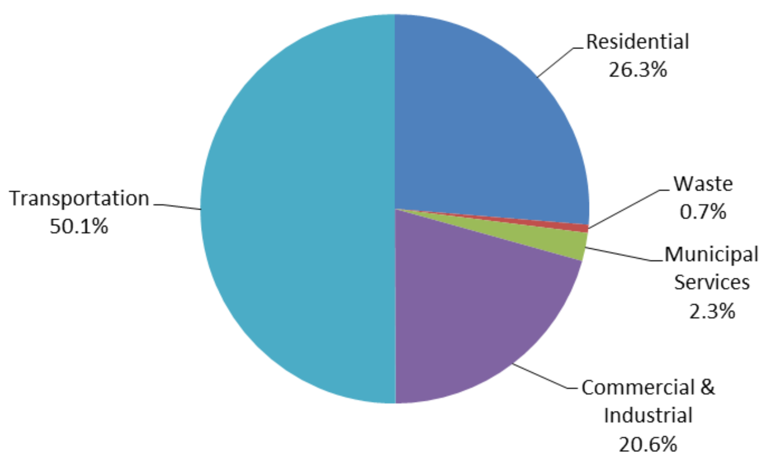


2.5 Town-wide GHG Emissions

The ESC has used software developed by ICLEI USA to convert energy use, transportation, water/wastewater, and solid waste/recycling data into units of CO_2e, or carbon dioxide equivalent, the internationally recognized measure of GHG emissions. Details of the calculation methodology are included in Appendix E, including conversion factors for energy units, water volume, trash weight, etc.

The overall GHG emissions for Stoughton in 2009 are estimated to be at least 321,637 tons of CO_2e. This is equivalent to a per capita emissions rate of 11.8 tons per person annually. This is comparable to the average citizen in Massachusetts, 13.84 tons per person per year (29). The distribution of GHG emissions from the various sources that have been studied is illustrated in Figure 2.5.1 below.

Figure 2.5.1
Distribution of GHG Emissions by Sector



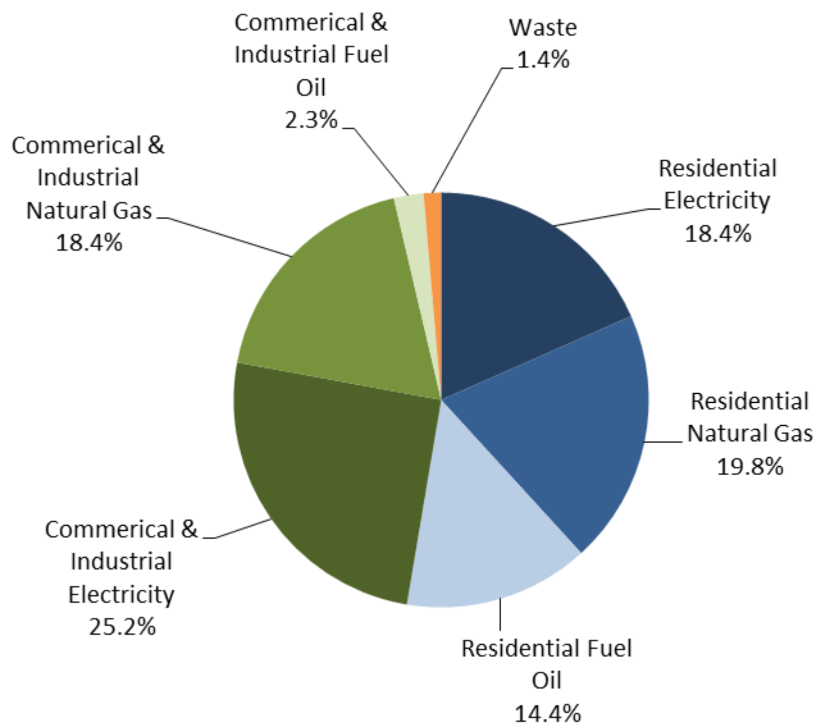
It appears that the greatest single source of emissions is from vehicles passing through town boundaries, and most of this is on Route 24. Unfortunately, this source of emissions is largely beyond the control of the town. However, given that many residents commute beyond town boundaries to work, the inclusion of the Route 24 data may provide a rough approximation of the emissions associated with Stoughton's commuters.

Focusing on the non-transportation emissions, there appears to be a balance among residential and commercial/industrial emissions. Heating fuels (natural gas and fuel oil) represent 55% of the carbon emissions and electricity represents 44%. Residential emissions represent 53% of the total while commercial and industrial emissions represent 46%. Figure 2.5.2 presents this information graphically.

Residential heating represents the largest source of non-transportation emissions (35%). Methods of reducing emissions can entail conversion to natural gas and propane, improving heating equipment performance, reducing uncontrolled air infiltration, and properly insulating structures. Columbia Gas is seeking to connect as many customers as possible, and all customers are eligible to participate in the MassSave incentive programs. National Grid and Columbia Gas coordinate the efforts of residential energy performance consultants that provide free audits and recommendations. The town may be able to reduce its GHG emissions and save its citizens money by encouraging them to have an energy audit.

Figure 2.5.2

Distribution of Non-Transportation GHG Emissions by Sector and Fuel Source



The second largest non-transportation source of emissions is commercial and industrial electricity use (25%). There is a wide range of end uses that consume electricity, but the most common are lighting and plug-powered equipment. Lighting technologies are evolving quickly, and National Grid is eager to help its commercial and industrial (C&I) customers identify and carry out cost-effective retrofit projects. Other assistance is provided to optimize existing heating, ventilating, and air conditioning (HVAC) systems. National Grid can recommend energy efficiency engineers that specialize in helping their customers optimize process performance and participate in the MassSave incentive programs. ESC member Eric Studer can help commercial entities in town connect with the appropriate contact at National Grid to get an energy efficiency scoping study initiated.

C&I heating represents 21% of the GHG emissions, and most of this is likely to be from gas customers. The MassSave gas efficiency programs are now similar to the electric programs in terms of application process, degree of rigor, and incentive amounts. Most opportunities for reducing heating energy use and GHG emissions are likely to be gained from reducing uncontrolled infiltration and properly controlling ventilation airflow rates.

Residential electricity represents 18% of the GHG emissions. Most of this energy is likely to be used by lighting, food storage, water heating, clothes drying, and plug-powered equipment such as televisions and computers. Replacement of old appliances with high performing EnergyStar equipment, use of compact fluorescent lamps, and conversion to gas for clothes dryers and water heating are standard ways to reduce energy use, costs, and GHG emissions. Newer generations of products, such as heat pump water heaters, are likely to become more common in the future, and MassSave may offer new incentives to facilitate this market change.

Residential waste was quantified by the committee, but its collection and disposal at a controlled incinerator that generates electricity does not appear to represent a very large fraction of non-transportation emissions (1%). The ICLEI software tool used to develop GHG values did not have a module to account for recycling impacts nor could the transport of the waste to the incinerator be taken into account. Future versions of this study should use different software.

The relatively small impact of residential waste on the overall GHG emissions value suggests that there is not much error introduced to the analysis by not quantifying the C&I waste volume.

The ESC believes that this study provides a reasonable GHG emissions benchmark for the Town of Stoughton: 321,637 tons per year. Future studies will build upon what was learned and will be able to generate a more comprehensive GHG emissions value. Given the difficulty in obtaining some information at this time and the likely improvements in information gathering, care will need to be taken when comparing future GHG emissions estimates to the value presented in this report.

Chapter 3: Municipal Services Greenhouse Gas Emissions and Resource Use

The energy consumption and greenhouse gas emissions of municipally owned and operated property, including the schools, represents a relatively small fraction (2.3%) of the overall emissions considered in this report. However, energy costs represent a large portion of the town operating budget. Therefore, understanding how energy is used by town facilities is critical to making decisions about how best to reduce these costs. The intent of this section is to create a basis for evaluating the impacts of current and future energy conservation and efficiency initiatives undertaken by the town.

Electricity and natural gas consumption data for 2009 have been gathered from MassEnergyInsight, and fuel use has been provided by the Department of Public Works (DPW). The ESC is grateful to Joel Harding of the Stoughton Public Schools and Jonathan Beder of the Stoughton DPW in assisting with the configuration of the MassEnergyInsight energy tracking tool (30).

For the sake of brevity, this chapter primarily contains figures, tables, and charts describing 2009 energy use, CO_2 generation, and operating costs. The charts are intended to identify the largest sources of GHG emissions and operating costs. If the town wishes to achieve substantial reductions in emissions and costs, targeting facilities with the largest emissions and operating costs is likely to yield the greatest return.

There has not been an effort to consolidate cost data for all of the utility accounts given the variety of billing rates, fluctuations in commodity prices, and potential future changes in energy purchasing contracts. Operating cost information presented in the following charts is based on general rates typical of commercial accounts at the time that this report is being released, see Table 3.0.1 below. Future comparisons of operating costs should be based on the following rates, or data for 2009 should be updated to future typical prices.

Table 3.0.1
Carbon Content and Relative Prices of Fuel Sources

	Average Rate	CO2 Emissions	lb CO2 per $1 Spent
Electricity	$0.100 per kWh	1.004 lb/kWh	10.04 lb/$
Natural Gas	$1.100 per therm	2.412 lb/therm	2.19 lb/$
Diesel Fuel	$3.000 per gallon	22.20 lb/gallon	6.47 lb/$
Gasoline	$3.25 per gallon	19.40 lb/gallon	6.83 lb/$

Data for the 95 electrical accounts, 31 natural gas accounts, and 25 vehicle fuel accounts used in this analysis can be found in Appendix D.

3.1 Emissions and Costs by Fuel Type

The town primarily uses four fuel sources: electrical energy from National Grid, natural gas from Columbia Gas, and diesel and gasoline from Global Partners. Additional energy from the burning of waste oil at the DPW buildings is not taken into account in this analysis since it is unlikely to significantly impact operating budgets or CO_2 emissions. As shown in Figure 3.1.1 and Figure 3.1.2 below, electricity consumption has a much larger carbon impact relative to its cost and constitutes the largest sources of municipal CO_2 emissions. This suggests that minor reductions in electricity expenditures will have greater impacts on carbon emissions. It is likely that New England will continue to generate most of its electricity from natural gas, and this relationship between emissions and cost will probably be valid going forward.

Figure 3.1.1
CO_2 Emissions by Fuel Type

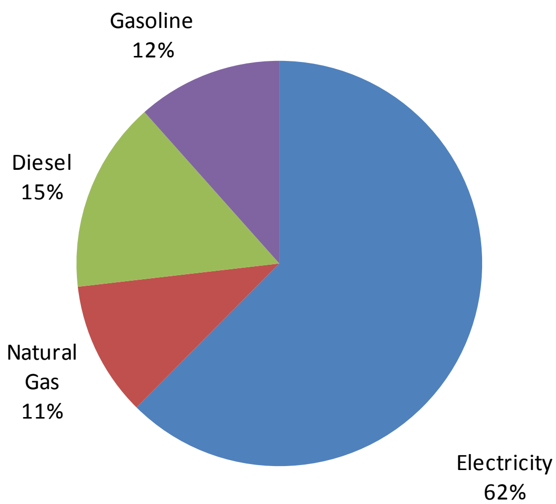
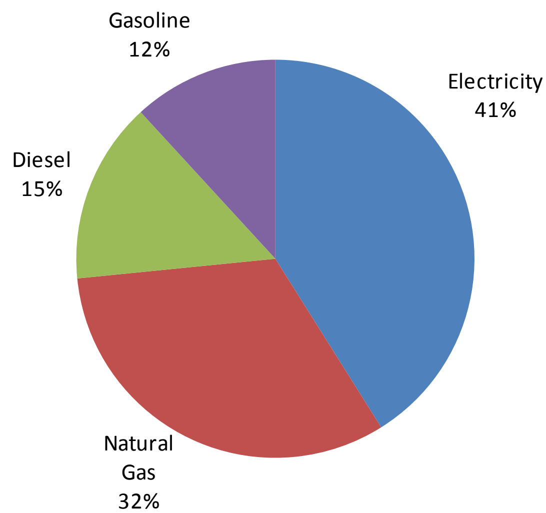


Figure 3.1.2
Cost by Fuel Type



The term "division" is used in this report to group similar types of buildings based on services provided. The service divisions include the town entities shown in Table 3.1.1 below.

Table 3.1.1
Municipal Service Divisions

Division	Town Departments
DPW	Water, Sewer, Sanitation, Ice/Snow, Recreation, Forestry and Highway Departments
Town Admin	Town manager, Engineering and Building Departments, Visiting Nurses, Assessor's Office, and Housing Authority
Schools	Stoughton Public Schools
COA / YC	Council on Aging and Youth Council
Police	Police Department and Animal Control
Fire	Fire Department
Golf Course	Cedar Hill Golf Course
Historical Society	Clapp Memorial Library
Library	Stoughton Public Library

The distribution of emissions and operating costs by municipal division is illustrated in Figure 3.1.3 and Figure 3.1.4 below. A summary of actual consumption, emissions, and approximate operating costs are presented in Table D7 in Appendix D.

Figure 3.1.3
CO_2 Emissions by Division

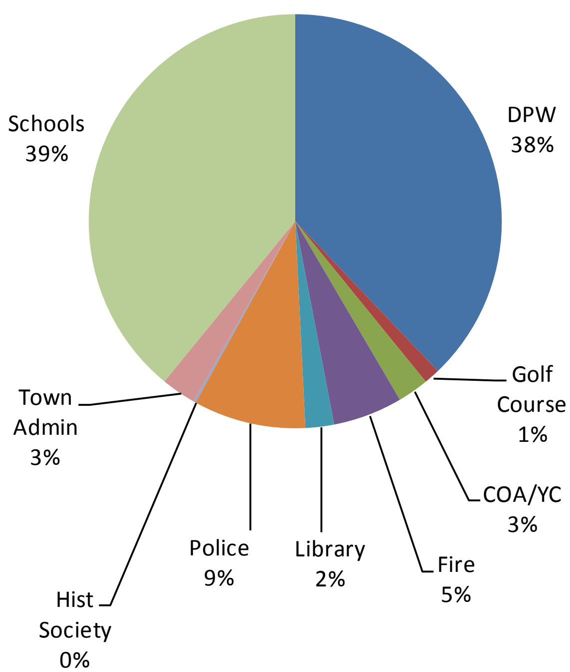
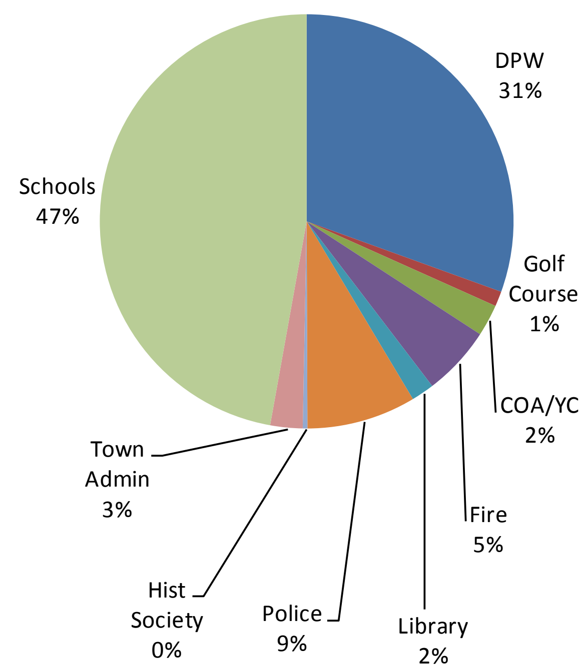


Figure 3.1.4
Costs by Division



3.2 Emissions by Service Division

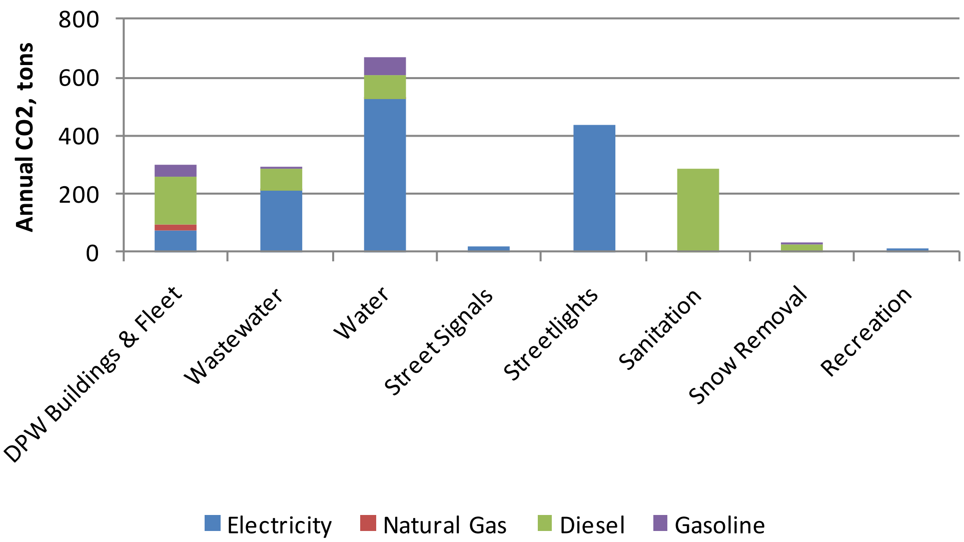
The following figures present a breakdown of CO_2 emissions by fuel source for the DPW, schools, and other municipal service divisions. The discussions that follow focus on the largest CO_2 sources reflected in each figure. For reference, maps showing the locations of main town facilities are included in Appendix C as Map 5 (schools) and Map 6 (town services).

<u>Department of Public Works</u>

The DPW handles all work pertaining to street maintenance, water supply, wastewater collection, and open space maintenance. The sources of carbon emissions from the various divisions within the DPW are illustrated in Figure 3.2.1 below.

Supplying water to the town represents the greatest source of carbon emissions for the DPW. Water pumping data from calendar year 2010 for the seven well stations indicate that the town's water system required 2,350 kWh for every million gallons of water pumped. This is equivalent to 1.18 tons of CO_2 per million gallons delivered. This value does not include electricity purchased by the Massachusetts Water Resources Authority (MWRA). Town received 30% of its water from the Canton interconnection in 2010. The ESC has not been able to determine the wire-to-water performance of the MWRA system, but it is likely that importing water from western Massachusetts has a greater carbon footprint than water pumped from municipal sources. The DPW only provided detailed data for the seven well stations for 2010, and this is considered to be roughly equivalent for 2009.

Figure 3.2.1
CO_2 Emissions for Stoughton DPW



Most water provided by the town to residents and businesses needs to be disposed of through the town's system of sewers and lift stations. The Sewer Department has utility accounts at 10 locations, and the total electricity use was 415,417 kWh in 2009. With a total of 1,398 MG pumped for treatment by the MWRA, the performance of the town's collection system is 297 kWh/MG. This is equivalent to 0.15 tons of CO_2 per million gallons collected. Treatment at Deer Island generates 0.64 tons of CO_2 per million gallons. Ignoring pump energy required to move wastewater from Stoughton to Deer Island, approximately 0.79 tons of CO_2 are generated for every million gallons of wastewater and infiltration originating in Stoughton.

Street lighting is one of the largest electrical end uses in town. Patterns of electricity consumption reflect the impacts of longer summer days and longer winter nights. Stoughton is unique since it owns all of its streetlights, whereas most communities lease streetlights from the utilities. The DPW has already taken steps to reduce streetlight energy use by reducing the wattage of most pole lamps. Further conservation strategies could include turning off selected lights during early morning hours.

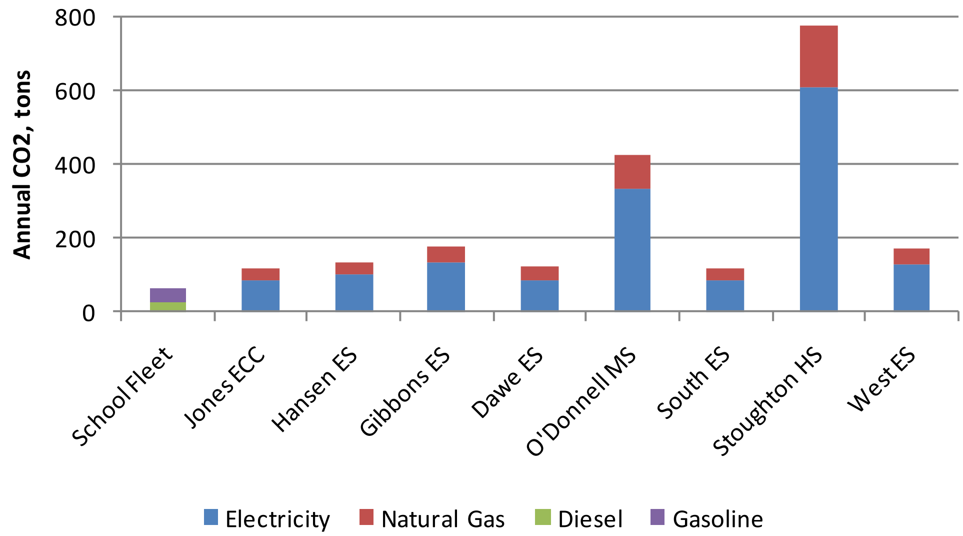
Diesel fuel is consumed by heavy work vehicles, large pickup trucks, generators, and equipment. Fuel consumption could potentially be reduced by adopting and enforcing policies that limit idling. The installation of an improved vehicle fuel tracking system could allow poorly performing vehicles to be identified; this information can inform decisions regarding replacement.

Stoughton Public Schools

The Stoughton Public School District conditions and illuminates 638,000 ft^2 of educational and recreational floor space in eight buildings. As can be seen in Figure 3.2.2, the high school is clearly the largest consumer of energy and the largest source of CO_2 among the schools. As discussed above, electricity has a greater carbon footprint than natural gas. Most electricity is used in the schools for lighting and operation of fans. There is relatively limited use of air conditioning. The schools took steps to reduce electricity consumption in the summer of 2009 when lighting in all eight buildings was upgraded.

Note that this analysis does not include the GHG impacts of leased school bus services but does include the fuel use of maintenance and the limited number of pupil transportation vehicles it does own and operate, except for the one bus owned by the district. The schools lease transportation for the students, and it is assumed that they do not have control over the fuel efficiency or emissions controls on the buses. The schools do operate a limited number of vehicles for specialized transport and maintenance, and the fuel consumption of this small fleet, including the single bus, is included in Figure 3.2.2 below.

Figure 3.2.2
CO_2 Emissions for Stoughton Public Schools

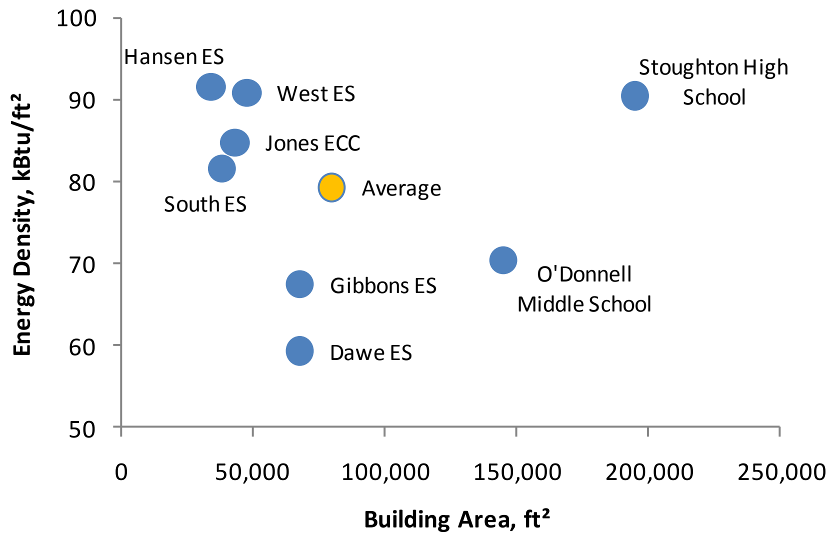


The energy performance of buildings can be compared by converting fuel use to a common unit of measurement and by dividing the total energy use by the floor area. Figure 3.2.3 below illustrates the energy performance of the schools. As a point of reference, a new building built to code may achieve 60 kBtu/ft². A high performance building using advanced heating, ventilation, and air conditioning (HVAC) and lighting technologies may be able to achieve 50 kBtu/ft² or less (30). The average energy performance of Stoughton's school buildings, 79 kBtu/ft², is typical of older schools. In general, larger buildings tend to have better energy performance values than smaller buildings due to improved building massing and also due to the use of larger, more efficient HVAC equipment and more complex control systems.

Figure 3.2.3 below indicates that the high school presents the greatest opportunity for energy savings. It has much greater energy use than the other buildings, and the normalized energy consumption (kBtu/ft²) is fairly poor. Ideally, the energy performance of the high school would be better than or equivalent to the middle school since it is a larger building. The older portion of the building has a steam heating system and poor space temperature controls. Summer use of the high school needs to be taken into account when reviewing these results; the other buildings tend not to be used during summer break.

The Jones Early childhood Center (ECC) was built in the 1940s, and the five elementary schools were primarily constructed in the 1950s and 1960s. The town's facilities master plan report indicates that the mechanical systems have been found to be nearing the end of their expected service life spans. It may be possible to improve the energy performance of the poorest performing schools with boiler upgrades and relatively simple improvements to HVAC controls. Replacement of failing unit ventilators with newer, more efficient units having reliable outside air damper controls will probably be a cost-effective option.

Figure 3.2.3
Energy Performance of School Buildings



Other Town Services

The source of carbon generation for the remaining town service divisions are shown in Figure 3.2.4 below. The police department is required to operate its vehicles nearly constantly, so it is not surprising that gasoline consumption is its single largest CO_2 generation source.

Figure 3.2.4
CO_2 Emissions for Other Municipal Services

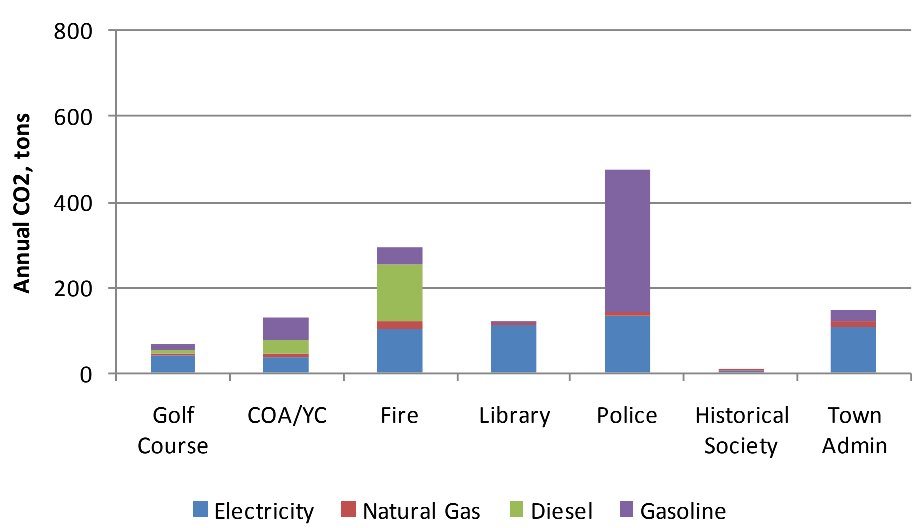
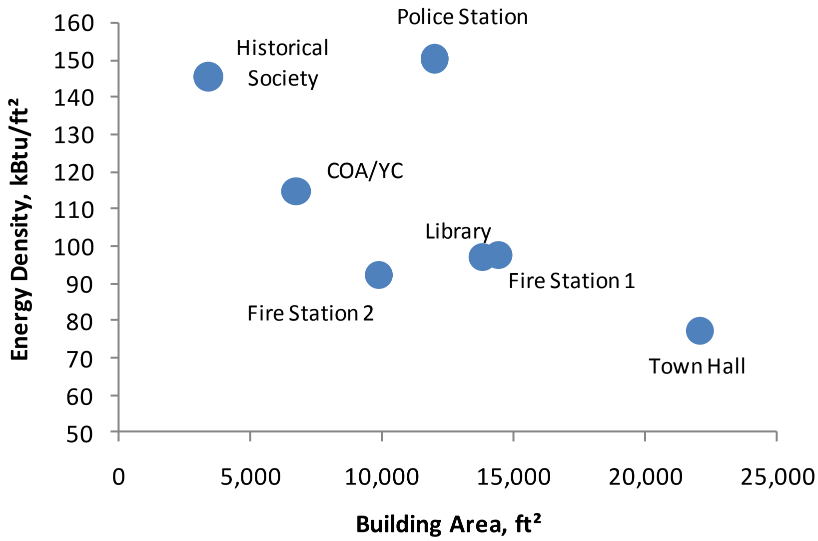


Figure 3.2.5 below presents the energy performance of non-school buildings, excluding DPW buildings. While the schools have relatively similar hours of operation, some town buildings operate for more hours

per year than others. It is expected that the police and fire stations will use more energy than the Clapp Library on a square foot basis since the stations are manned 24/7 and the Clapp Library is typically unoccupied. Ideally, the energy performance of these buildings would be approximately 90 kBtu/ft² for air-conditioned buildings that are constantly occupied and 65 kBtu/ft² for buildings following an office schedule. Inadequate information is available at this time to include the various DPW buildings in Figure 3.2.5.

Figure 3.2.5
Energy Performance of Municipal Buildings



The Clapp Library (Historical Society) uses a great deal of energy for its size and typical hours of operation. This suggests that there may be a high degree of airflow through cracks and gaps in the walls and roof, a poorly performing steam heating system, and/or a great deal of lighting use.

Since the police and fire stations are manned continuously, they could be expected to display similar energy use and energy use density. However, the police station's energy use and density are significantly higher than either fire station, suggesting that considerable savings are possible. (It should be noted that Fire Station No. 2 may not have been fully occupied for all of 2009 due to mold remediation issues.)

The Town Hall is performing as would be expected for an older office building. This is not to say that there are not opportunities for improvement, but upgrades may not produce as great a benefit as improvements to the police station.

3.3 Combined Results

The results contained in CO_2 and cost charts presented above are combined in Figure 3.3.1 and Figure 3.3.2 below. Building performance data are combined in Figure 3.3.3. These comprehensive charts can help focus the efforts of the Town's energy conservation and efficiency efforts.

Figure 3.3.1
Sources of CO_2 Emissions

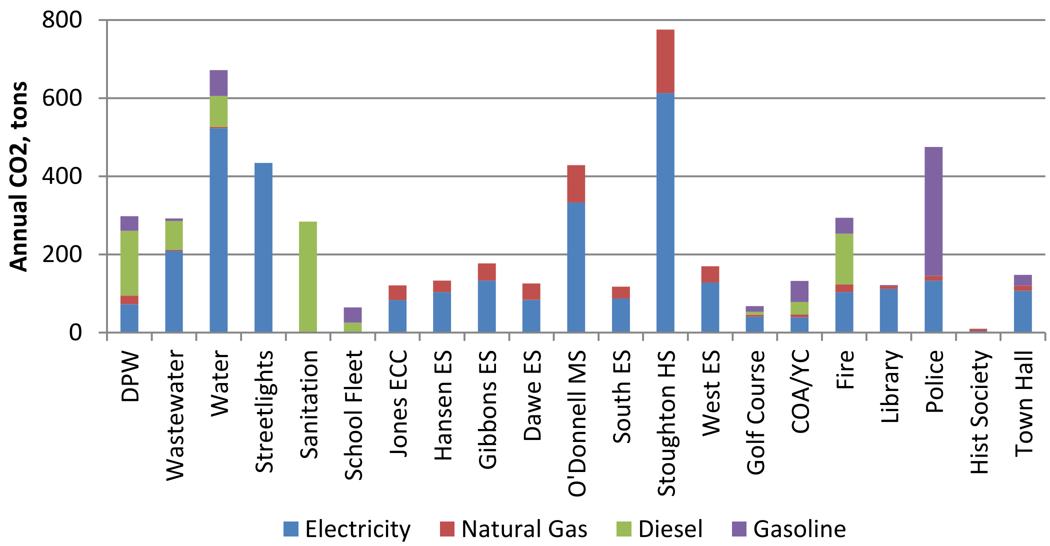


Figure 3.3.2
Approximate Energy Expenditures

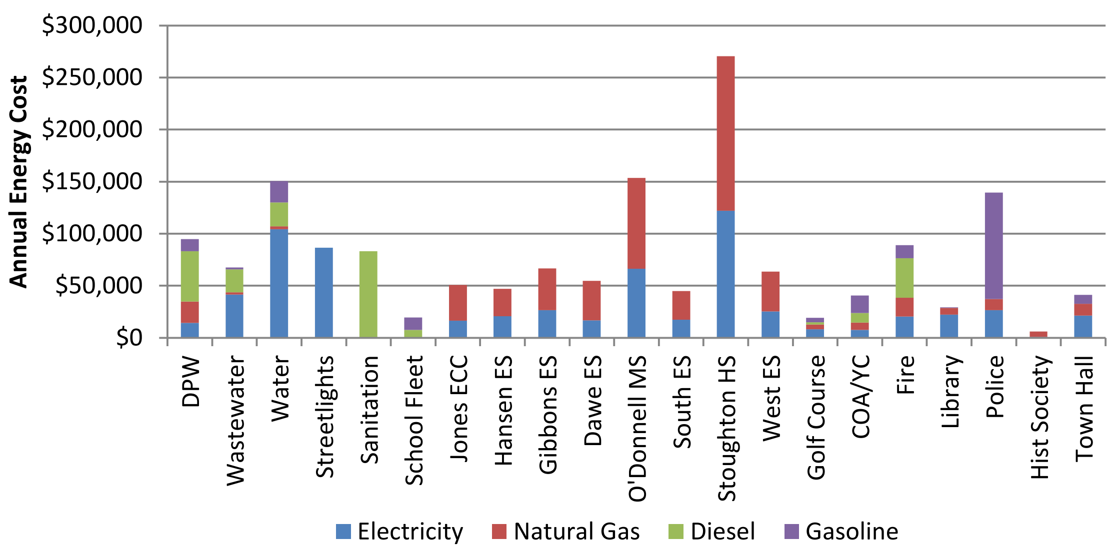
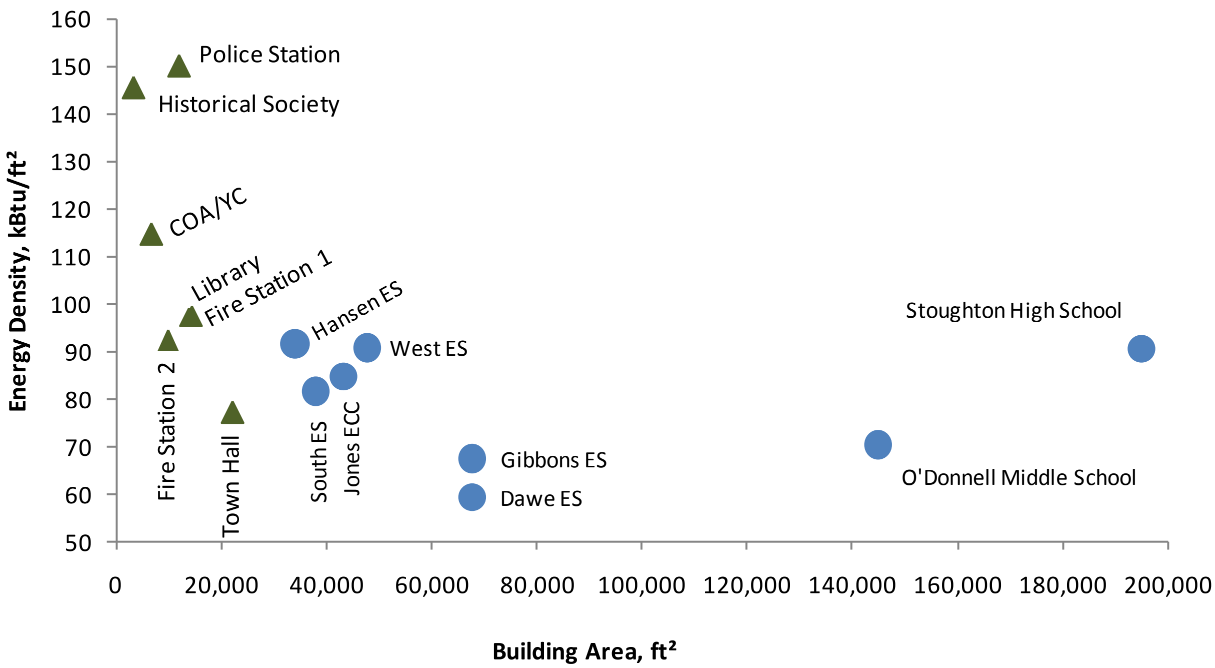


Figure 3.3.3
Building Energy Performance Comparison



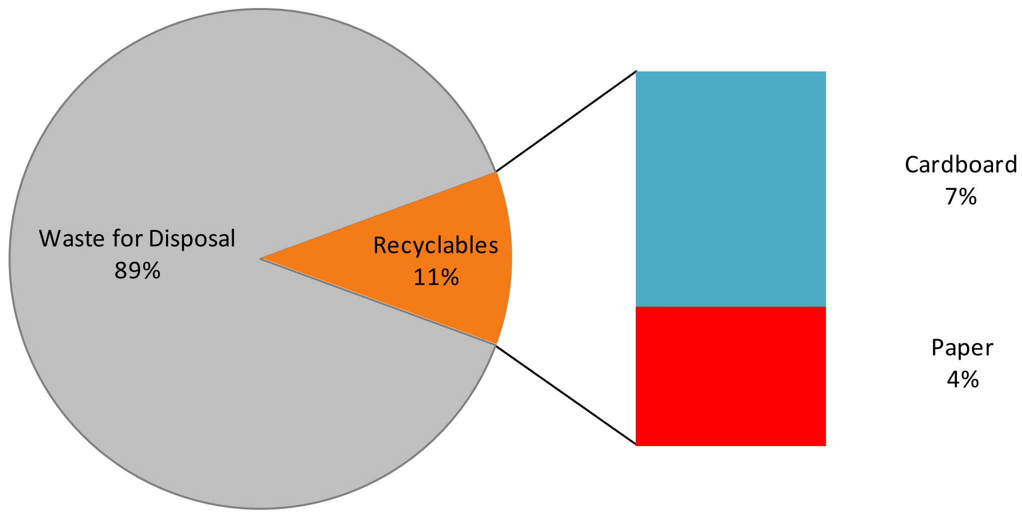
3.4 Town Services Solid Waste

There is currently no formal recycling program in town buildings and a partial recycling program in the schools. There are significant opportunities for expanded recycling efforts in the town's institutions that will help reduce Stoughton's solid waste diversion rate.

The Stoughton Public School District is responsible for arranging its own solid waste and recycling services. The district contracts with a private hauler for waste collection and disposal and for cardboard recycling. Paper recycling is overseen by individual schools' Parent Teacher Organizations or, in the case of Stoughton High School, by the Recycling Club. Cardboard and paper are the only materials recycled at the schools.

In 2009, Stoughton's public schools disposed of 1,663 tons of waste and recycled a total of 210 tons of cardboard and paper, resulting in a recycling rate of 11%, as shown in **Error! Reference source not found. Error! Reference source not found.**. The committee did not have information for other informal recycling efforts made by town departments.

Figure 3.4.2
Stoughton Public Schools Waste Disposal and Recycling Rates



3.5 Town Services Benchmark Information

The overall energy use of Stoughton was 87,880 million Btu in calendar year 2009. The associated CO_2 emissions are estimated to be 5,396 tons. Including non-carbon GHG emissions, the municipal emissions are 7,521 tons. This is the baseline that the Stoughton Energy & Sustainability Committee will use for future analyses of the town government's energy performance.

Chapter 4: Suggested Next Steps

Stoughton is in a good position to proactively address many issues that pertain to GHG emissions reductions. Energy conservation and water conservation reduce direct costs and associated fees that residents, businesses, and town government need to pay. There are many programs with funds to support private and public efforts to reduce resource consumption. The ESC has developed this report to identify the most promising areas to focus on given opportunities for significant GHG reductions and outside assistance. As an overarching recommendation, the committee suggests that the Stoughton Board of Selectmen, School Department, and citizen groups embrace the GHG emissions targets described in the 2008 Global Warming Solutions Act and 2010 Massachusetts Clean Energy and Climate Action Plan to actively work with Stoughton's residents and businesses to help achieve these goals.

4.1 GHG Reduction Efforts

If the town is to meet the RGGI goal of a 10% reduction in GHG emissions by 2018 and the state's goal of a 25% reduction by 2020, Stoughton's residents, businesses, and town agencies will need to take specific steps to reduce energy use and waste production. Our analysis indicates that outreach should be focused on the following major efforts:

- Encourage all residents to take advantage of free energy audits and to follow up on the recommendations provided
- Encourage residents to explore the installation of solar generation equipment and to take advantage of incentive programs
- Reduce waste volume through increased recycling and composting
- Adopt the Stretch Energy Code to require high performance new construction
- Encourage all commercial and industrial companies to explore incentive opportunities for their processes and equipment
- Encourage industrial and commercial users of town water to conserve
- Set a GHG/energy reduction target to be achieved within the next 5-8 years
- Complete updates to the GHG inventory to allow tracking of energy use and GHG emission reduction successes

4.2 Municipal Services Operating Cost Reduction Efforts

The ESC encourages the DPW, schools, and other municipal entities to strive for improved energy performance in all publicly supported facilities. The data gathered as part of this analysis suggest that the most significant improvements may lie in the following areas:

- Minimizing infiltration into the wastewater system
- Optimizing the HVAC systems at the high school and middle school
- Reducing water consumption, which will have an associated impact on wastewater flow rates
- Considering fuel efficiency when purchasing new police vehicles
- Upgrading police station HVAC systems
- Considering high-performance options during replacement of HVAC equipment

- Reducing the number of streetlight operating hours if they are not required for public safety in early morning hours
- Adopting and enforcing anti-idling policies for DPW vehicles, which may save considerable fuel
- Including life-cycle cost analyses when making planning and purchasing decisions
- Considering creation of an energy efficiency fund that can be used to finance the additional cost of identifying, studying, and implementing upgrade projects. This fund would receive all incentives from the MassSave program, and the town could contribute a nominal amount each year based upon the amount of energy saved by previous projects.

4.3 ESC Next Steps

This report represents the first major work product of the Energy & Sustainability Committee. A baseline or existing condition study is a necessary pre-requisite for any planning effort. Moving forward, the committee is hoping to be able to produce the following:

Data Collection Guide

Many pieces of information were gathered to produce this report, and identifying what could not be found was as instructive as what we did find. The committee will be issuing a follow-up document to this report with recommendations for the town and schools for data to keep. Grant opportunities supporting GHG emission reductions are likely to materialize in the future, and having data such as what is included in this report readily at hand may help Stoughton obtain funding.

Green Communities Grant Program Application

Assembling the application to be designated a Green Community under the DOER's current Green Community Grant Program requires the town to look at its operations and regulations in a different way. Whether it is reviewing the zoning guidelines to determine how friendly Stoughton is to alternative energy research, determining how to reduce energy use by 20% in five years, figuring out how many vehicles the town operates, or starting a dialog about construction standards, the benefits of striving to meet the requirements of the grant program is a good planning tool. Each of the criteria is intended to create the basis for a more energy efficient economy.

Sustainability Action Plan

The development of an action plan can help focus the efforts of the ESC, other town committees, and public service groups in the community. The concept of sustainability can mean many different things in different contexts. A plan can help define what sustainability means for Stoughton, and it should include economic, municipal budget, pollution, water resource, climate, energy, and community ambitions. The ESC may serve as co-facilitators with other community groups who may already be having discussions surrounding the creation of a sustainability plan.

Appendix A: References

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Appendix B: Stoughton Energy & Sustainability Committee

The Stoughton Energy & Sustainability Committee (ESC) is a volunteer citizen's advisory group to the Town's Board of Selectmen focusing on issues pertaining to developing sustainable community practices by evaluating energy consumption, greenhouse gas emissions, water consumption, wastewater generation, and solid waste generation and recycling. The Committee has four goals that characterize its mission:

- The reduction of fossil fuel energy use in Stoughton,
- The quantification of energy and resource use via a town-wide greenhouse gas inventory,
- The provision of information to Town agencies and residents about sustainability, climate change, and energy and resource conservation, and
- The production of cost savings for the Town and residents through resource conservation and improved energy efficiency.

Below is a brief listing of some of ESC activities since its inception in fall of 2009 to date:

- First committee meeting—October 8, 2009
- Committee meetings approximately every two weeks—Fall 2009 to date
- Energy and environmental inventory data collection—February 2010 to date
- Presentation by Mr. Seth Pickering, the Southeast Massachusetts Regional Green Communities Coordinator, on the Green Communities Program—April 21, 2010
- Committee minutes available on the Town of Stoughton website—May 12, 2010
- Committee tours the IKEA building, the only United States Green Building Council (USGBC) recognized green building in Stoughton—May 19, 2010
- Green Communities Program Presentation to the Stoughton Board of Selectmen with Seth Pickering, the Southeast Massachusetts Regional Green Communities Coordinator, on the Green Communities Program—August 8, 2010
- Submission of stretch code article to spring Town Meeting—January 3, 2011
- Presentation to the Town Planning Board about the requirements for the Green Communities Program—January 13, 2011
- Draft energy study of the Stoughton water system, currently being reviewed by DPW
- Development of this report – January 2010 through May 2011

Committee Members

David Billo is a geologist and environmental scientist at Sovereign Consulting in Mansfield, MA. At Sovereign, David manages the cleanup of oil and hazardous materials releases and conducts indoor air quality assessments. David is a Leadership in Energy and Environmental Design Accredited Professional (LEED AP). David and his wife Kathy have three daughters and have lived in Stoughton since 1993. David is the chairman of the committee.

Mike Fisher is a LEED accredited professional working as a construction manager on large institutional projects. Mike is a life-long resident of Stoughton.

Patricia Hogan, Ph.D., is currently a tenured Associate Professor of Physics at Suffolk University and a LEED AP. Pat's background is in chemical/environmental engineering and chemistry, and prior to teaching at Suffolk, she worked as a senior environmental engineer at engineering consulting firms and a health and safety consultant. Pat has lived in Stoughton since 1982 and has raised two children here. Pat served as vice-chairman of the committee in 2010.

Tony Phillips is a Facility Coordinator at Digitas, an advertising agency in Boston, handling day to day administrative operations. Tony has been a Stoughton resident since 1994 and is married with three children. Tony is the committee secretary for 2011.

Jill Somers has been in regular attendance at ESC meetings since January 2011 and became a member of the committee in April 2011. Jill is a Biological Scientist for Novartis Institutes for Biomedical Research, where she studies Gene-Drug Interactions. She and her husband Derek grew up in Stoughton and continue to make their home here with their young son Brendan.

Hollyce States is Director of Grants at Massasoit Community College. She has served on Massasoit's Sustainability Task Force since its inception in 2007 and was a member of the team that wrote the college's Climate Action Plan. Holly and her husband Jeff have lived in Stoughton since 1981 and raised their two daughters here. Holly served as secretary of the committee in 2010.

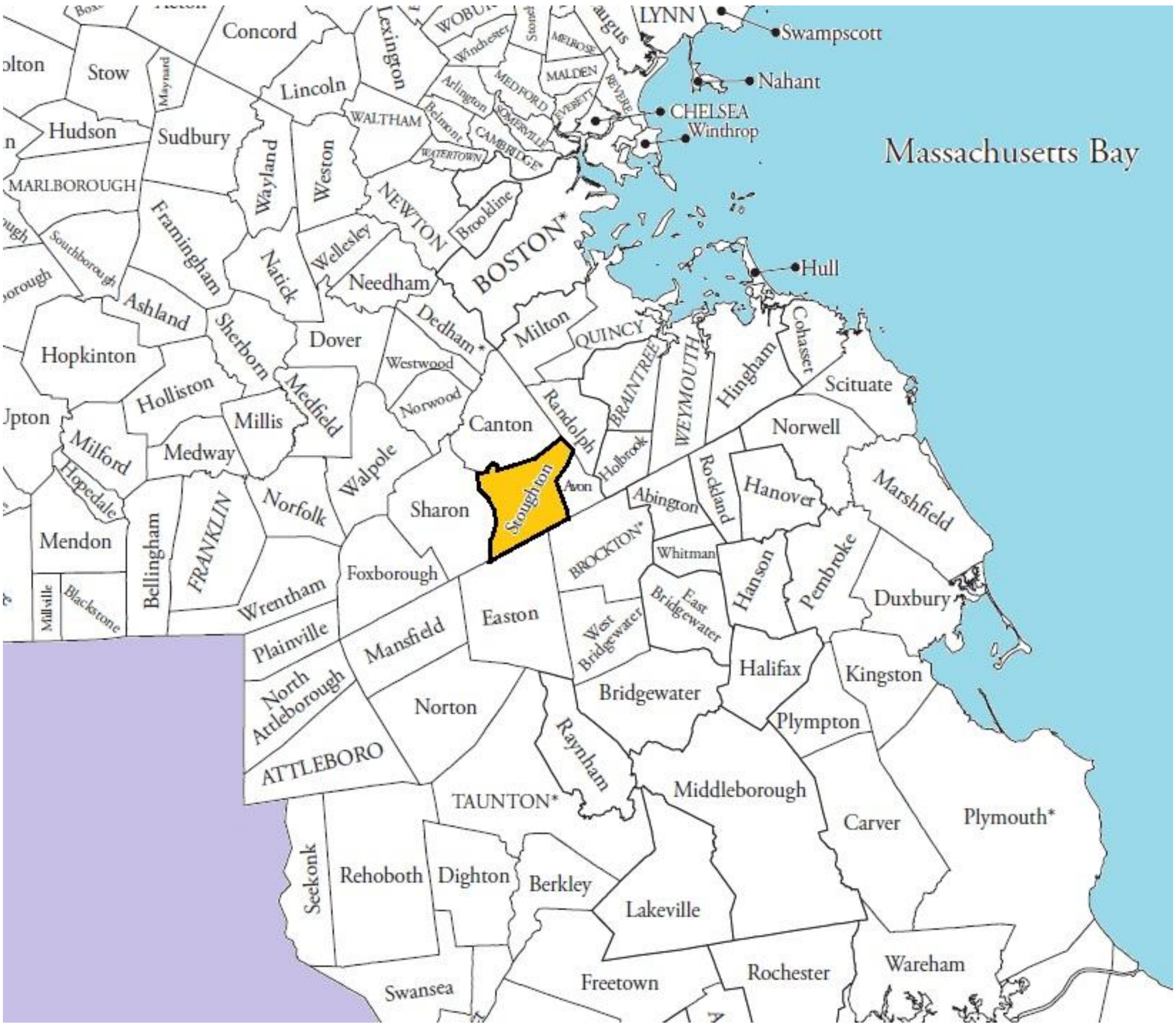
Eric Studer, PE, is a registered mechanical engineer who works in the field of energy efficiency. Through his past work at Demand Management Institute (DMI) from 2001 to 2011, he has assisted regional utilities, facility owners, institutions, and municipalities in identifying cost effective energy efficiency retrofit projects. Eric also serves on design teams to optimize new designs. He recently established his own independent practice, TNZ Energy Consulting, Inc, which is based in Stoughton. Eric has lived in Stoughton since 2008 and is originally from a small town in northwest Ohio. Eric is the vice-chairman of the committee in 2011.

John Anzivino is the committee's liaison to the Board of Selectmen and brings a great deal of experience and perspective to the group. John is the lead electrical designer for National Grid's Substation Engineering Control and Integration department and has been a resident of Stoughton since 1979. John was re-elected to a second three-year term on the Board of Selectmen in April 2011.

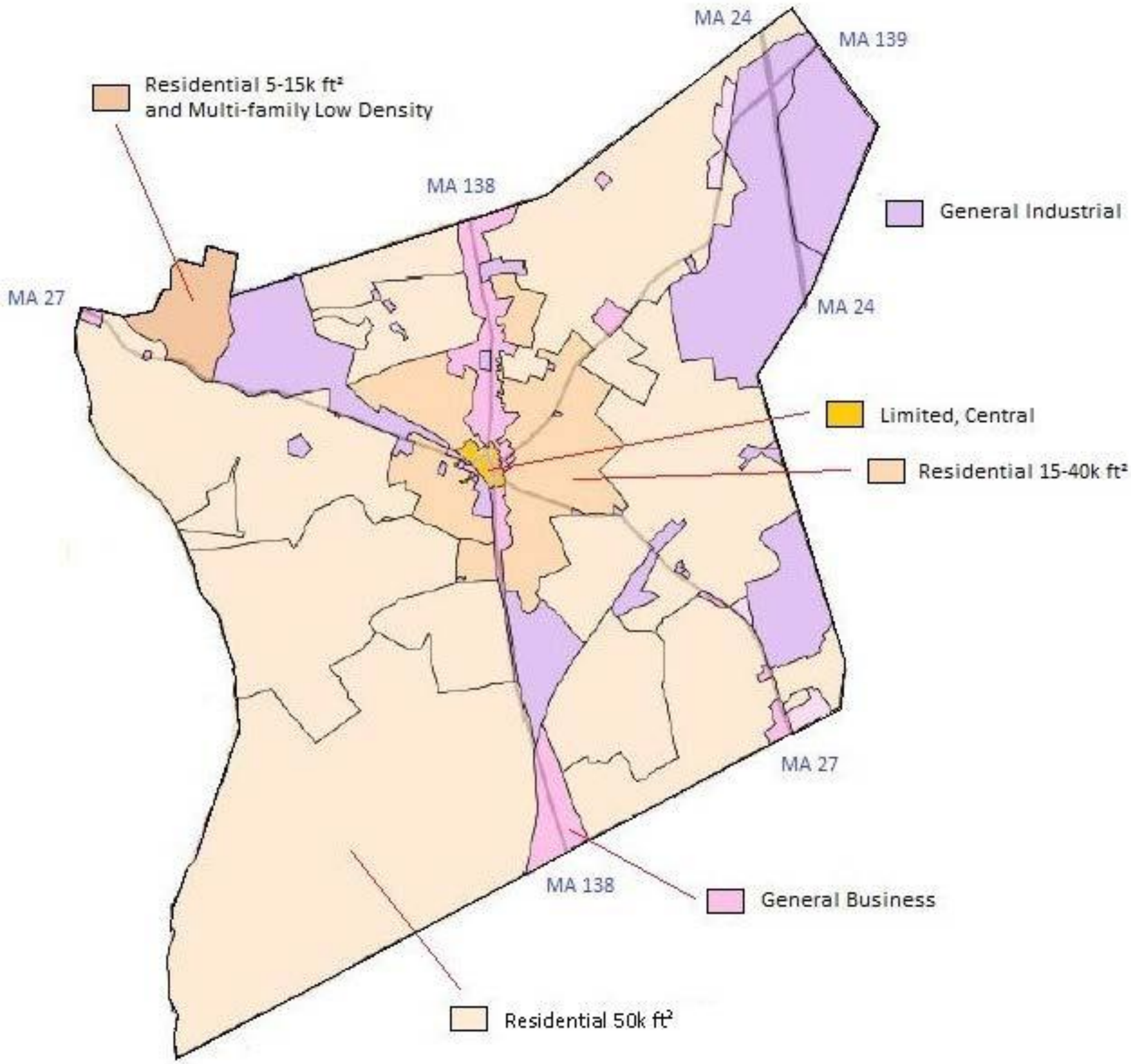
Although not a formal member of the committee, ***John D'Addieco*** has attended many of the committee's meetings and has contributed valuable insight and advice.

Appendix C: Town Maps

Map 1
General Map of Region

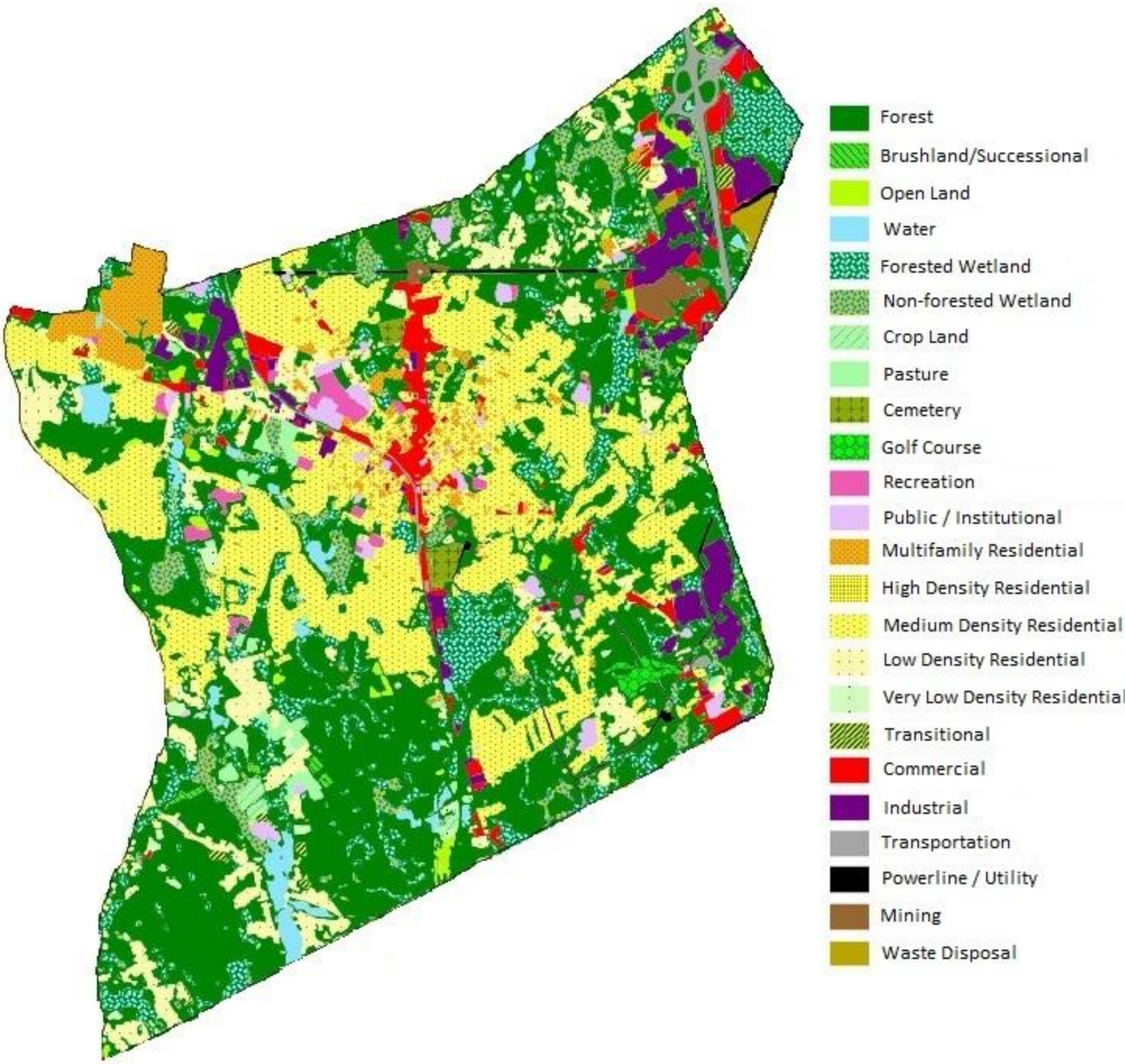


Map 2
Stoughton Zoning Map



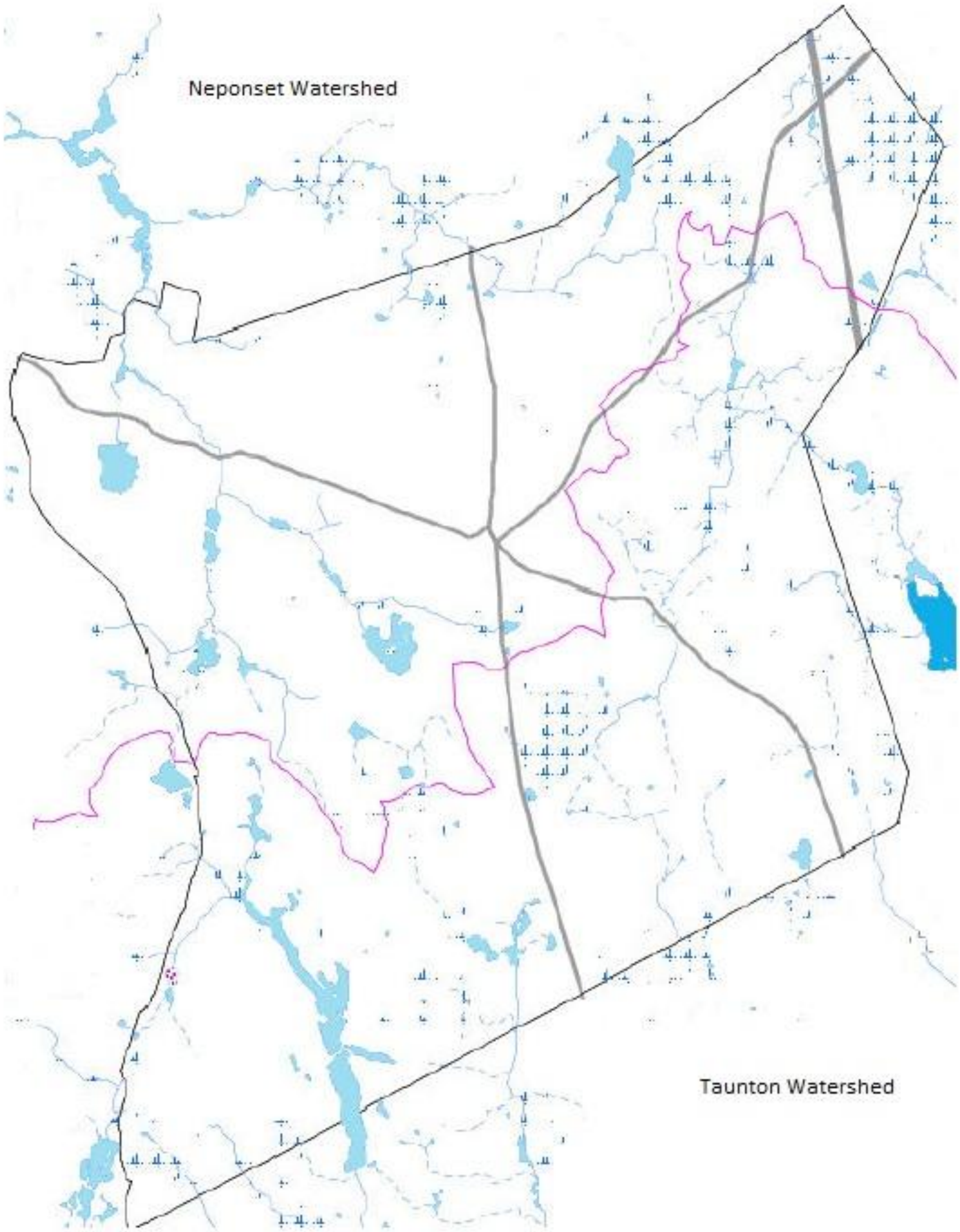
Source: MassGIS OLIVER

Map 3
Stoughton Land Use, 2005



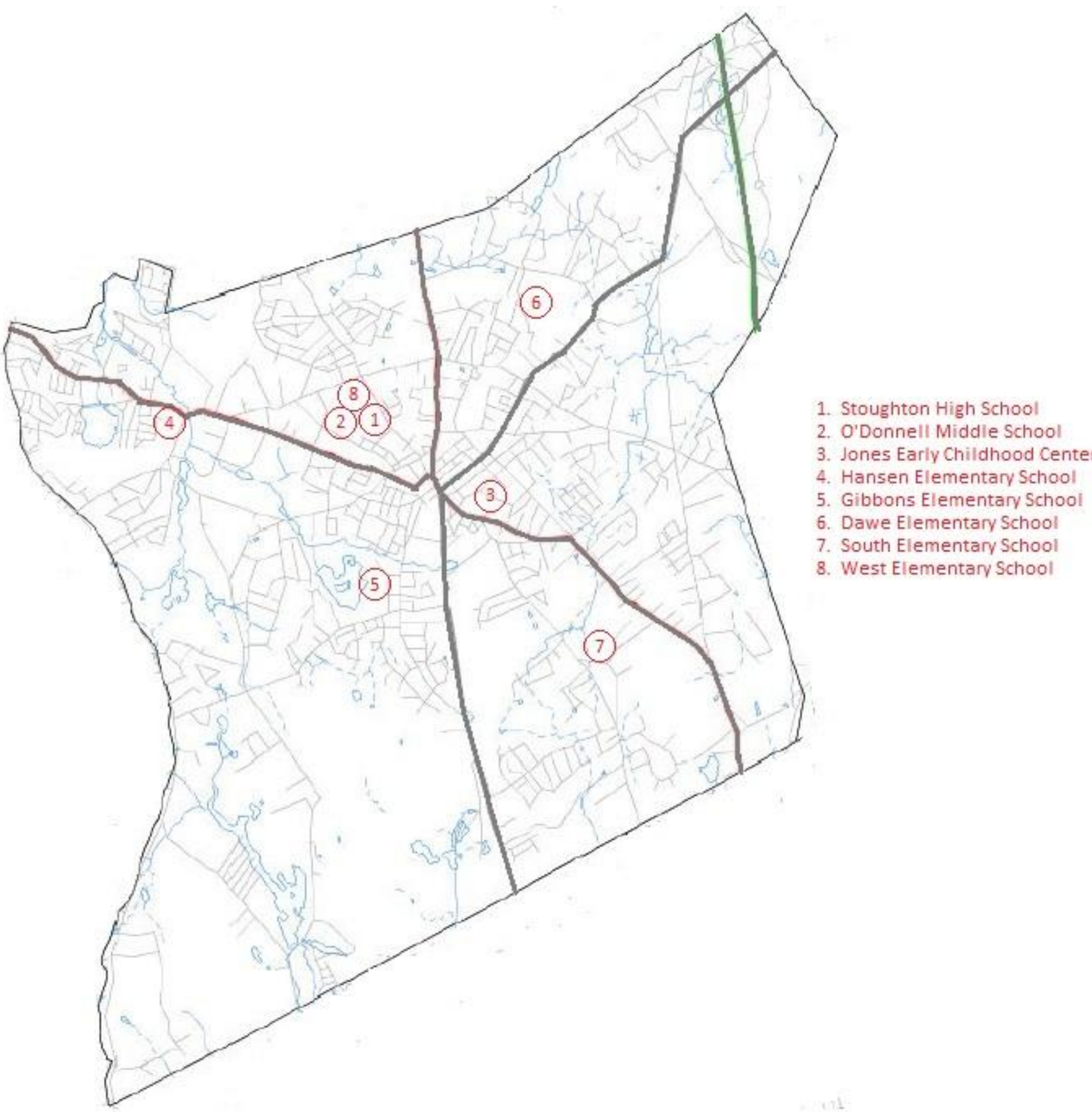
Source: MassGIS OLIVER

Map 4
Watersheds



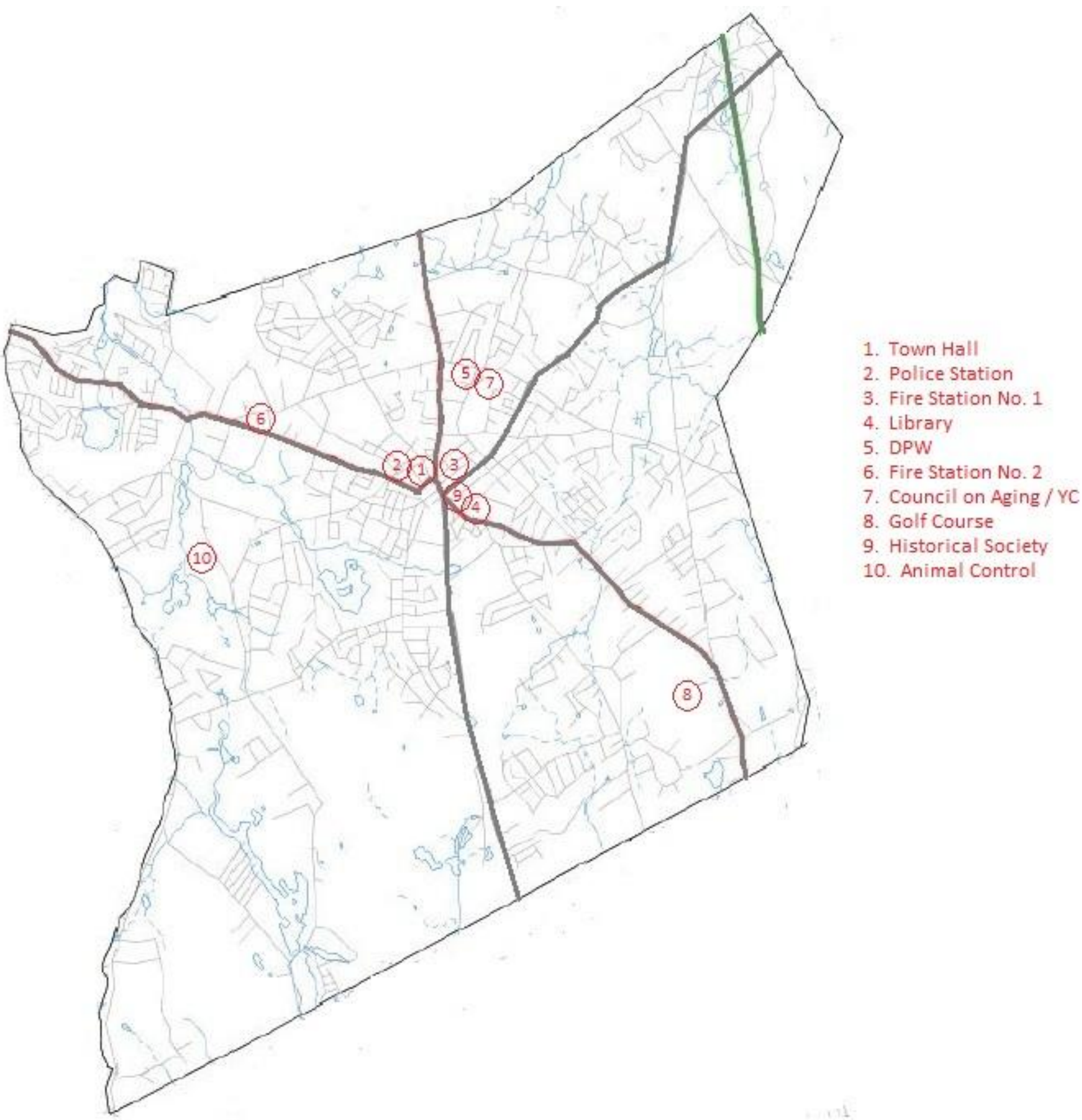
Source: MassGIS OLIVER

Map 5
Stoughton Public Schools



Background Source: MassGIS OLIVER

Map 6
Public Service Facilities



Background Source: MassGIS OLIVER

Appendix D: Supporting Information

This appendix contains raw data used in the development of the results presented in the main body of the report. Additional background information, such as contact information for sources of data, is also included.

Selection of the Baseline Year

The baseline year of calendar year 2009 was selected because it presented the most recent full year's worth of data available at the time that this study was first being discussed and because its average temperature did not fluctuate substantially from the historical average, making it a reasonable basis for comparison. The calendar year, rather than the town's fiscal year, is used since most GHG emissions are generated by non-municipal sources and since most residents and businesses use the standard calendar year.

Electricity Consumption

Aggregate data for National Grid customers were provided by the town's account manager, June Brady Wooding (June.Bradywooding@us.ngrid.com, 508-482-1203), who works out of the NGrid's Brockton office. Tabular data are included below. Selectman John Anzivino wrote a letter to the electric company requesting that the data be released to the committee.

The number of NSTAR electric customers in town is limited, and data for their consumption were not gathered. Future studies may wish to include this energy consumption. It is likely that the account manager serving commercial customers in Sharon will be the best contact.

Table D1
National Grid Electricity Use and Account Data

Date	Electrical Energy Consumed				Number of Accounts			
	Residential		Commercial		Residential		Commercial	
	Standard kWh	Elect Heat kWh	Small kWh	Large kWh	Standard No.	Elect Heat No.	Small No.	Large No.
Jan-09	6,955,227	298,294	8,148,994	1,153,210	10,077	207	1,560	65
Feb-09	7,395,582	343,023	8,190,371	1,207,968	10,176	211	1,575	68
Mar-09	6,605,007	275,716	8,041,810	1,171,019	10,192	214	1,570	71
Apr-09	5,900,933	243,939	7,752,314	1,221,873	10,195	215	1,587	68
May-09	5,738,710	161,961	7,359,474	1,097,486	10,155	210	1,574	67
Jun-09	5,527,175	130,914	7,650,209	1,313,293	10,133	214	1,580	67
Jul-09	5,597,663	126,049	7,922,454	1,259,312	10,163	214	1,570	68
Aug-09	7,407,093	154,347	8,690,088	1,348,332	10,158	210	1,590	69
Sep-09	9,374,781	172,196	8,980,612	1,344,539	10,159	208	1,567	67
Oct-09	5,685,663	131,208	7,559,098	1,195,009	10,157	213	1,564	67
Nov-09	5,325,894	157,054	7,227,045	1,145,699	10,147	209	1,562	66
Dec-09	6,402,869	219,169	8,068,858	1,293,703	10,206	210	1,573	68

Natural Gas Consumption

Aggregate data for Columbia Gas customers were provided through the Municipal Project Manager, Matt Zenni (508-836-7322). Tabular data are included in the table below. Selectman John Anzivino wrote a letter to the gas company requesting that the data be released to the committee, and used the following address:

Michael Harn
Commercial Field Sales Representative
Bay State Gas Company
995 Belmont Street
Brockton, MA 02301

Data for propane consumption could not be gathered at this time given the uncertainty of the number of households and businesses that use site-stored natural gas and due to the variety of suppliers serving the town. It is recommended that future versions of this report include an extrapolation of gas use to estimate propane use.

Table D2
Bay State Gas Use and Account Data

Date	Natural Gas Consumed			Number of Accounts		
	Residential		Commercial	Residential		Commercial
	Standard therms	No Heat therms	Accounts therms	Standard No.	No Heat No.	Accounts No.
Jan-09	1,013,396	11,548	846,472	5,508	510	871
Feb-09	974,697	9,636	958,517	5,505	506	870
Mar-09	772,367	9,189	735,838	5,506	507	864
Apr-09	570,942	8,422	529,915	5,492	505	842
May-09	299,274	6,935	314,491	5,483	507	828
Jun-09	158,870	5,550	158,790	5,468	508	822
Jul-09	136,667	5,647	137,681	5,474	507	823
Aug-09	103,952	5,005	108,544	5,469	503	821
Sep-09	109,342	5,053	114,928	5,471	502	822
Oct-09	146,677	5,034	147,816	5,501	498	836
Nov-09	405,681	6,737	325,516	5,511	502	846
Dec-09	467,897	7,058	413,921	5,490	501	847

Fuel Oil Consumption

The ESC made an attempt to estimate fuel oil consumption based on data from local suppliers, but found that companies that were contacted were reticent to provide the information or do not log their delivery data in a manner that would facilitate this kind of information request. Future versions of this report should use more developed data than the estimation method based on natural gas use.

The Stoughton Assessor's Office provided the ESC with data pertaining to the number of residences and businesses that are listed as having oil fired heating systems. These data were provided on many sheets of paper, and the original data are not included in this document. Paula Keefe of the Assessor's Office worked with Tony Phillips of the ESC to provide this information.

Transportation

The most easily obtained data regarding transportation covered the total number of vehicle miles traveled within town borders. Scott Peterson, Central Transportation Planning Division (scottp@ctps.org, 617-973-7078) provided the information presented in tabular form below.

Future versions of this report may be able to use vehicle inspection records from the state to determine the total number of miles driven by vehicles owned/garaged within Stoughton. Insurance industry databases may be able to provide similar data. This kind of information will provide a better indication of the success of efforts to change driving habits, vehicle purchasing decisions, and/or public transit use of town residents.

Table D3
Vehicle Miles Traveled Data

	Morning		Mid-day		Afternoon		Night		Daily	
	Miles	lb CO_2	Miles	lb CO_2	Miles	lb CO_2	Miles	lb CO_2	Miles	lb CO_2
Single Occupant Vehicles	88,640	109,107	129,310	159,152	116,010	142,771	100,140	123,260	434,100	534,290
High Occupancy Vehicles	19,170	23,589	41,060	50,530	32,000	39,375	37,060	45,614	129,290	159,107
Commercial Vehicles	19,280	23,722	42,370	52,139	20,000	24,626	19,200	23,634	100,850	124,120
Hazardous Cargo Vehicles	460	573	1,130	1,389	390	485	450	551	2,430	2,998
Vehicle Total	127,550	156,991	213,870	263,210	168,400	207,256	156,850	193,059	666,670	820,515
Passenger Commuter Rail	14	1,036	11	772	14	1,036	18	1,301	57	4,145

Source: CTPS Retional Travel Demand Model, Base Year version April 2010
Morning: 6:00 - 9:00
Mid-day: 9:00 - 15:00
Afternoon: 15:00 - 18:00
Night: 18:00 - 6:00

Water Use

The DPW provided data on water consumption for customers connected to town water.

Table D4
Town Water Supply Volumes

Name	Watershed	Status	2009 Volume	Treatment		
				pH Adjustment	Chlorine	Fe/Mn Removal
Muddy Pond (No.1)	Neponset	Active	119.852 MG	X	X	
Harris Pond (No. 2)	Neponset	Active	146.010 MG	X	X	
Fennel (No. 3)	Taunton	Active	0 MG	X	X	
McNamara (No. 4)	Taunton	Active	0 MG	X	X	
Gurney (No. 5)	Taunton	Active	78.844 MG	X		
Pratt's Court (No.6)	Neponset	Active	59.015 MG	X	X	X
Goddard (No. 7)	Taunton	Active	60.4226 MG	X	X	
MWRA/Canton	Chicopee	Active	189.830 MG			
Easton Water Dept	Taunton		1.650 MG			
Sharon Water Dept	Taunton		0.230 MG			
Randolph Water Dept	Neponset		0.034 MG			
Canton Water Dept	Neponset		1.280 MG			
Total			657.167 MG			

Wastewater Generation

The town maintains records of all wastewater volumes that are billed each quarter and also has records of monthly discharge volumes to the MWRA collection system. Data used in this report are single values provided by the DPW and MWRA reports. Data is presented in the main text of the report.

Solid Waste Management and Recycling

The data collected by the DPW for residential solid waste and recycling tonnage for calendar year 2009 are shown in the table below. The data cover waste and recyclables collected curbside from residential buildings housing three or fewer families, recyclables collected at the Stoughton Recycling Center, and solid waste tonnage collected via dumpsters at municipal buildings (excluding school facilities).

Waste is transported 31 miles to SEMASS Covanta in Wareham where it is incinerated to generate electricity. In 2009, the 699 trips would have consumed approximately 6,200 gallons of diesel fuel (assuming an average fuel performance of 7 miles per gallon).

Table D5
DPW Solid Waste Data

Month	Trucked Waste		Glass, Plastic, Metal		Newspaper		Cardboard
	No. of Loads	Total Tons	No. of Loads	Total tons	No. of Loads	Total tons	Total tons
Jan-09	58	653.7	29	36.2	30	25.6	-
Feb-09	50	592.8	30	33.7	25	25.8	-
Mar-09	55	676.2	34	35.4	30	25.0	-
Apr-09	58	738.9	30	34.6	30	29.1	3.0
May-09	64	773.1	35	39.3	31	28.8	0.2
Jun-09	59	764.1	31	61.6	0	2.0	-
Jul-09	62	840.4	39	69.3	28	0.0	0.4
Aug-09	57	733.4	37	68.9	31	0.0	-
Sep-09	61	742.1	39	67.9	26	0.0	-
Oct-09	56	723.8	23	25.1	20	19.8	16.6
Nov-09	55	691.7	35	26.8	35	33.7	-
Dec-09	64	794.6	37	28.0	37	34.1	1.4
Total	699	8,724.7	399	526.9	323	224.0	21.6
Composted Leaves, Christmas Trees, etc					2,724.00 tons		
Other Residential Waste					966 tons		

Solid waste and recycling information for the schools is presented in the following table. Information was provided by Joel Harding, at the Stoughton Public Schools (j_harding@stoughtonschools.org , 781-344-4000, ext. 1227).

Table D6
School Solid Waste Data

Building	TRASH*				CARDBOARD**				PAPER***	
	Container Size	Pick Ups	Loose YDS/YR	Tons	Container Size	Pick Ups	Loose YDS/YR	Tons	Container Size	Tons
SHS	*6 YD COMPACTOR*	130	2,340	526.5	6 YD LOOSE	44.0	264.0	26.4	2-6 YD	11.9
FIELD HOUSE	6 YD LOOSE	30	180	40.5						
OMS	*6 YD COMPACTOR*	95	1,710	384.8	6 YD LOOSE	44.0	264.0	26.4	6 YD	13.0
JONES	6 YD LOOSE	52	312	70.2						
HANSEN	6 YD LOOSE	95	570	128.3						
SOUTH	6 YD LOOSE	95	570	128.3					6 YD	14.4
WEST	6 YD LOOSE	95	570	128.3	6 YD LOOSE	44.0	264.0	26.4	6 YD	11.4
DAWE	6 YD LOOSE	95	570	128.3	6 YD LOOSE	44.0	264.0	26.4	6 YD	11.4
GIBBONS	6 YD LOOSE	95	570	128.3	6 YD LOOSE	44.0	264.0	26.4	6 YD	15.8

*Cubic yards of mixed solid waste converted to tons using EPA guidelines: uncompacted: 1 cubic yd. = 300-600 lbs., or 450 lbs. average

**Cubic yards converted to tons using DEP's recommended volume-to-weight conversion for loose, unbaled cardboard: 200 pounds / cubic yard

***Paper recycling is done through PTOs and SHS recycling club. Tonnage provided by hauler, Abitibi Consolidated, Inc.

Municipal End Uses

Energy consumption data for municipally owned and operated facilities are currently being tracked by the town and by the MA Department of Energy Resources (MA DOER) through MassEnergyInsight. This powerful tool allows municipalities to see up-to-date electricity and natural gas consumption for all accounts in one interface. Data for fuel oil, diesel fuel, gasoline, propane, and other energy sources need to be entered into the database by the municipality.

The town has 95 electrical accounts and 31 natural gas accounts. The complete list of accounts and monthly energy use data for calendar year 2009 is attached at the end of this appendix. A summary of this data is presented below in Table D8. Vehicle fuel consumption data were provided by the DPW and are presented below in Appendix D.

Heat provided by the burning of waste oil at the DPW highway garage is not included in the analysis. An estimate of the volume of oil that is disposed of each year could be made by reviewing the amount of motor oil that is purchased and used during the typical year.

Table D7

Energy Use, Emissions, and Approximate Cost Data Summary

	Electricity kWh	Nat Gas therms	Diesel gallons	Gasoline gallons	Energy MMBtu	CO2 tons	Op Cost
Golf Course	80,430	4,202	640	1,488	947	67	$19,210
COA/YC	76,558	6,225	2,857	5,554	1,887	132	$40,450
Fire	205,182	16,218	11,735	4,169	4,317	293	$89,005
Library	222,720	5,810	0	216	1,366	121	$29,311
Police	264,464	9,860	0	34,012	5,766	475	$139,328
DPW	2,529,360	23,013	56,666	12,060	19,644	2,043	$498,592
Hist Society	8,049	4,673	0	0	495	10	$5,945
Town Admin	212,992	10,331	0	2,860	2,086	147	$41,244
Schools	3,111,472	400,012	2,283	4,031	51,373	2,109	$770,673
	6,711,227	480,344	74,181	64,390	87,880	5,396	$1,633,758

Table D8

Town Vehicle Fuel Consumption

Department	Diesel gallons	Gasoline gallons
Police/Animal	-	34,011.8
Fire	11,735.3	4,169.0
Engineering	-	426.6
Town Manager	-	886.2
Visiting Nurses	-	132.4
Assessor's Office	-	417.7
Housing Authority	-	813.0
Council on Aging	2,857.0	5,553.9
Library	-	215.9
Schools	2,282.7	4,031.4
Building	-	184.4
Cedar Hill	640.1	1,488.1
Sewer	6,704.3	695.2
Administration	14,897.5	3,891.7
Water	7,115.2	6,805.6
Sanitation	25,559.7	-
Snow/Ice	2,388.9	667.1

Appendix E: GHG Emissions Calculation Methodology

The following information is taken from the supporting documentation included in the help file of the GHG calculation software used by the committee. The software was developed by the Tellus Institute for ICLEI USA. Further Details of the research provided by the Tellus Institute in the development of the CACP software emission factors included at the end of this appendix can be obtained directly from the Institute.

Clean Air and Climate Protection Software

This software was developed by Torrie Smith Associates (TSA) for Cities for Climate Protection - US Projects, (a project of the International Council for Local Environmental Initiatives), and for the U.S. State and Territorial Air Pollution Program Administrators (STAPPA) and the Association of Local Air Pollution Control Officials (ALAPCO). The Clean Air and Climate Protection Software (CACPS) helps the user to:

- Create an inventory and forecast emissions of greenhouse gases (GHGs) and criteria pollutants, namely nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO), volatile organic compounds (VOCs) and coarse particulate matter (PM10),
- Evaluate policies to reduce emissions of these pollutants, and
- Prepare a GHG emission reduction action plan, with associated criteria pollutant co-benefits.

The components can be used independently (e.g., to evaluate a single measure), or can be used together to develop a comprehensive action plan. The software also generates reports that list the anticipated emission reductions of GHGs, NOx, SOx , VOCs, CO, and PM10 from the measure(s) or action plan, as well as cost savings and expected payback periods.

To develop an emission inventory Use the Analysis Module, choose a baseline year, and then enter energy use and waste data by sector as records in the inventory database. Use the Community Analysis Module to inventory community emissions as a whole, and use the Government Analysis Module to inventory emissions from government-controlled operations. The software tracks emissions from each entry and sums them to create your "inventory". You continue to add records until your inventory is complete. Data sets can be saved by year so the user can create inventories for additional years as desired.

To evaluate a proposed or existing measure Use the Measures Module to evaluate the impacts of specific measures (e.g., a proposed green power purchase). To do this, (1) click on the appropriate measures module (either Community or Government), (2) set the target year to the year your measure will be or was implemented (under Settings Targets tab), (3) choose the sector and type of measure, and then (4) enter the measure's energy data after choosing the units the correspond to your input data. The software indicates emissions reductions associated with this individual record (measure). This is useful if you want to obtain a simple estimate of the impact of a measure.

To develop a full climate action plan A full climate action plan consists of a baseline emissions inventory, a forecast of emissions by the target year, a reduction or avoidance target, and a quantified set of measures that add up to your target. To do this, (1) select both a baseline and forecast target year (e.g., 2000 and 2015) and use Analysis modules to create an inventory for both years (or, if you already have emissions inventory data for the baseline year and/or forecast years, directly enter the data into the Analysis module), (2) set an emissions reduction target to be achieved against the baseline year by the target year, (3) use the Measures Module to evaluate, track, and insert multiple policies and measures proposed into the database, and finally (4) generate the climate action plan using the CACPS reports features. In the process of developing the plan, you can periodically sum your measures to track progress towards meeting your target.

Community Analysis

This Help screen contains a general introduction to the Community Analysis module. For more details about specific aspects of how the module works or what information to enter, click on any green underlined text or, FOR ANY SCREEN, PLACE THE CURSOR IN THE AREA OF THE SCREEN ON WHICH YOU WANT HELP, AND PRESS F1. IMPORTANT NEW FEATURE IN CLEAN AIR AND CLIMATE PROTECTION SOFTWARE: SEE DIRECT INPUT OF INVENTORY DATA.

What Does This Module Do? The Community Emissions Analysis is one of the basic building blocks of developing a local action plan for greenhouse gas and air pollution emission reductions in your community. It is organized in six sectors -- residential, commercial, industry, transportation, waste, and "Other". With the aid of this module, you first develop an analysis of the emissions for the base year you have selected for your local action plan, and then develop an emissions forecast for the target year in your local action plan.

What Information Do You Need? For the all the sectors except Waste and Other, the key information you need to use this module is fuel and electricity consumption by sector (residential, commercial, industry, and transportation) for your community.

- For the residential, commercial and industrial sectors, local fuel and electricity providers will often have this type of information in the form of total sales by different customer classes.
- For the Waste sector, you need the total amount of waste generated and allocated to the various waste management alternatives, an estimate of the percent of methane recovered (if any) at the local landfills in the base year of your local action plan (the Help files have suggested defaults if you cannot get this), and a breakdown of the composition of the waste.
- For the transportation sector, for each fuel type, you need information on vehicle miles traveled by the different vehicle types represented in the software, and you need estimates of the fuel economy (miles per US gallon) for each vehicle type. (Default values are provided for fuel economy for each vehicle type and fuel combination). If you cannot get vehicle miles traveled from your transportation planning or traffic management department, try to get Annual Average Daily Traffic (AADT) counts by road type, along with the total length of each of those road types in your community. This data can be used in the VMT Calculator to make an estimate of VMT in your community.
- For the Other sector, you can simply input emissions of greenhouse gases and air pollution emissions directly that are not covered by the previous sectors.

The information above is needed to quantify greenhouse gas emissions and air pollution emissions for any particular year. In addition, for most of the sectors you can enter optional indicator inputs. These include: total number of households, total commercial sector employment, total commercial building floor area, total industrial sector employment, and total industrial sector building floor area. These indicator inputs are optional and do not affect the calculation of emissions and emission reductions.

How Does It Work? Use the Year Menu and click on Open to identify the year on which you wish to work -- this becomes the active year. The Community Analysis module is organized according to six sectors -- Residential, Commercial, Industrial, Transportation, Waste and Other. Click on one of the Sector Tabs to get started. For all sectors, information is stored in records, with each record corresponding to a group. Use the Record Navigator Bars to insert new groups, delete groups you no longer need, or to locate and select an existing group. Enter a unique name for the record or group in the Group Name Box. There is no need to have more than one group; some users maintain only a single record or group for each sector, with all energy use for that sector assigned to that single group record.

Under the Category tab, the Category List Manager gives you the option of defining up to three category lists for each sector that allow you to categorize each record in various ways (e.g. by neighborhood for Residential, by Building type for Commercial, etc.).

- For the Residential, Commercial, and Industrial sectors: In the Energy Inputs Table, enter the total fuel consumption for the sector, by fuel type. Air pollution and greenhouse gas emissions are calculated based on information you provide about total use of fuels and electricity in these sectors. This information is combined with emission factors to determine emissions. The software also supports the direct entry of emissions inventory data
- For the Transportation Sector: For each fuel, you can enter either VMT or fuel consumption by vehicle type. Greenhouse gas emissions are computed based on fuel consumed and air emissions are computed based on distance traveled and vehicle type. If you elect to enter transportation activity in units of VMT, the software will use the vehicle fuel efficiencies to compute greenhouse gas emissions; if you elect to enter fuel consumption data, the software will use the vehicle efficiencies to compute VMT and will then calculate criteria air pollutant emissions on that basis.
- For the Waste Sector: See the Waste Sector Primer for an explanation of the method and the factors used here. For each record, enter the quantity of waste and the waste management alternative used in the waste inputs area. Enter the percentage composition of this waste in the rightmost column of the Waste Composition Inputs Table. If landfill gas (methane) recovery was already being practiced in the base year of your local action plan, go to the Settings Menu and enter the appropriate Base Year Methane Recovery Factor under the Methane Recovery Factor option on the Settings Menu. The software assumes a default Base Year Methane Recovery rate of zero. With these inputs, the software computes methane emissions using the methane commitment method. Based on the information you provide about the amount of waste in your community, the waste management options employed, the composition of that waste, and the rate of methane recovery (if any) at the landfills, the software calculates the methane emissions that will eventually occur and assigns them to the active year, the year in which the waste was produced. The software can also calculate methane emissions occurring in the active year as the result of the accumulated waste already in landfills using the Waste-in-Place Method. A Waste-in-Place Assistant on this sector screen supports a calculation of methane emissions using this method. A toggle switch on the Waste-In-Place Assistant screen allows the automatic transfer of results from the Assistant to the "Other" sector of the Community Analysis module.
- For the Other Sector: In the "Other" sector, you can enter emissions directly in the Other Emissions Inputs screen.
- For All Sectors: Use the Notes regarding... box as a scratch pad. We recommend you record the source of the data and any assumptions or details you may wish to recall later. For example, this is a convenient place to note the names and telephone numbers of the people who have provided you with the data you used or that screen. There are also windows on all the sector screens where you can enter indicator inputs. These are used to compute indicators of energy use and greenhouse gas emissions, such as emissions per household (in the residential sector), or emissions per square foot of floor area (in the commercial buildings sector). These indicators, which are presented in the Indicators Report, serve as benchmarks that can help you to measure progress from year-to-year and compare emissions in your community with other communities. They are optional inputs and do not affect the calculation of emissions and emission reductions.

The current subtotals for the active sector are displayed in the Output Panel at the bottom of the window. For all five sectors, there is a Forecast Builder Assistant which helps you conduct your emissions forecast by quickly developing an emissions analysis for a future year (usually your target year) by starting with the active year (usually your base year) and scaling it up.

The Forecast Builder prompts you to provide growth rates for fuel consumption, waste production, and other key variables. These multipliers are used to create an emissions analysis for the forecast year, which you can then modify as you see fit.

NOTE: The emissions forecast for the target year should NOT include the impact of any existing or proposed measures in your local action plan. Its purpose is to provide a "business as usual" baseline against which the impact of your local action plan can be measured. Finally, there is a Report button on each sector screen that opens up a dialog box containing a menu of Community Analysis Report Options. See also Menu Commands Operating the Software Direct Entry of Emissions Inventory Data Community Measures Community Analysis Report Options Local Action Plan

Government Analysis

This Help screen contains a general introduction to the Government Analysis module. For more details about specific aspects of how the module works or what information to enter, click on any green underlined text or, FOR ANY SCREEN, PLACE THE CURSOR IN THE AREA OF THE SCREEN ON WHICH YOU WANT HELP, AND PRESS F1. IMPORTANT NEW FEATURE IN CLEAN AIR AND CLIMATE PROTECTION SOFTWARE: See DIRECT INPUT OF INVENTORY DATA.

What Does This Module Do? Developing your local action plan for emission reductions includes a plan for your community and a plan for in-house or government operations. This module computes greenhouse gas and air pollutant emissions from government operations based on information you provide about fuel and electricity use and waste production.

Scope: The municipal operations portion of the Emissions Analysis covers all buildings, facilities, operations, lands, programs, and vehicles owned and/or operated directly by the local government. The exception is public transit, which is included in the community-wide emissions analysis to facilitate comparisons with emission reduction measures, some of which likely include the encouragement of transit use. (Exception: While transit vehicle energy consumption is considered part of the Community Emissions Analysis, if the transit authority is part of the local government, then the fuel and electricity consumption of the transit authority's buildings, maintenance fleet, etc. can be included in the Government emissions analysis.)

This version of the software also allows for the inclusion in the government inventory the emissions associated with the local government's employee commute to and from work, but this is an optional component of the government inventory. You first develop an analysis of the emissions in the base year, and then develop an emissions forecast for the target year in your local action plan. The module has seven separate sectors for keeping track of emissions from local government operations: Buildings, Vehicle Fleet, Employee Commute, Street lighting, Water and Sewage, Waste, and Other. Click on the appropriate sector tab near the top of the screen to get started.

What Information Do You Need? For the Buildings, Streetlights, and Water/Sewage sectors, the key information you need is fuel and electricity consumption records. These will typically be available for your buildings from the building managers, for the water and sewage treatment facilities from the facilities operators, and for the streetlights from the department that pays the electricity bill (or in some cases from the electric utility).

In addition to energy consumption, the software accepts inputs on the associated fuel and electricity costs. Although it is not needed to compute greenhouse gas emissions, we recommend you input this cost information. It will allow you to track costs as well as emissions, which may prove useful as you develop, market, and implement your local action plan. You may find it easier to obtain records of expenditures on fuel and electricity than to get data on the consumption in physical units. If this is the case, you will have to calculate the physical units by dividing the expenditures by the unit costs (dollars per gallon, cents per kWh, etc.)

Within each sector, the level of detail you enter depends on the information that is available and how much detail you wish to track. For example:

For the Buildings Sector, you can enter the fuel and electricity consumption of every single building that is owned and operated by your local government individually, or you can enter it in groups that are useful or convenient for your own purposes (e.g. by department).

For the Vehicle Fleet and Employee Commute sectors, for each fuel type, you need information on vehicle miles traveled by the different vehicle types represented in the software, and you need estimates of the fuel economy (miles per US gallon) for each vehicle type. (Default values are provided for fuel economy for each vehicle type and fuel combination). See the transportation sector inputs Help topic for more details.

For the Waste sector, you need the total amount of waste generated and allocated to the various waste management alternatives, an estimate of the percent of methane recovered (if any) at the local landfills in the base year of your local action plan (the Help files have suggested defaults if you cannot get this), and a breakdown of the composition of the waste. There is an optional input box for haulage and tipping costs.

Finally, there is a place on the screen for some of the sectors where you can input a number of statistics we call indicator inputs. While not required for the computation of emissions, these indicator inputs are used to generate a report that includes indicators that are very useful for tracking your progress over time or for comparing your results with other cities and members of the Campaign.

The indicator inputs vary by sector.

- For Buildings, for each building or building group they include floor area, annual operating hours and number of occupants.
- For the Vehicle Fleet, for each vehicle or vehicle group they include Vehicle Miles and Number of Vehicles.
- For the other sectors, indicator inputs include the total number of streetlights (for Streetlights), the total volume processed (in cubic feet) (for Water and Sewage) and the total number of municipal employees (for Waste).

How Does It Work? Use the Year Menu and click on Open to identify the year on which you wish to work -- this becomes the active year. The module is organized according to seven sectors -- Buildings, Vehicle Fleet, Employee Commute, Street lighting, Water and Sewage, Waste, and Other. Click on one of the Sector Tabs to get started. For all sectors, information is stored in records, with each record corresponding to a group (of buildings, vehicles, streetlights, water and sewage facilities, etc.).

Use the Record Navigator Bars to insert new groups, delete groups you no longer need, or to locate and select an existing group. Enter a unique name for the group in the Group Name Box. A Category List Manager gives you the option of defining up to three category lists for each sector that allow you to categorize each record in various ways (e.g. by building type for the Buildings Sector). If you have set up such lists, they will appear directly below the Group Name Box in one or more category selection boxes. Each category list you have set up will have a pull-down list of the category items you have defined; click on the category that best describes the group. For the Buildings, Streetlights, and Water/Sewage sectors, enter energy use by fuel in the Energy and Cost Inputs Table, fuel and electricity costs can also be entered here, but are optional.

Air pollution and greenhouse gas emissions are calculated based on information you provide about total use of fuels and electricity in these sectors. This information is combined with emission factors to determine emissions. The software also supports the direct entry of emissions inventory data For the Vehicle Fleet and Employee Commute Sectors, for each fuel, you can enter either VMT or fuel consumption by vehicle type. Greenhouse gas emissions are computed based on fuel consumed and air emissions are computed based on distance traveled and vehicle type. If you elect to enter transportation activity in units of VMT, the software will use the vehicle fuel efficiencies to compute greenhouse gas emissions; if you elect to enter fuel consumption data, the software will use the vehicle efficiencies to compute VMT and will then calculate criteria air pollutant emissions on that basis.

For the Waste Sector: See the Waste Sector Primer for an explanation of the method and the factors used here. For each record, enter the quantity of waste and the waste management alternative used in the waste inputs area. Enter the percentage composition of this waste in the rightmost column of the Waste Composition Inputs Table. If landfill gas (methane) recovery was already being practiced in the base year of your local action plan, go to the Settings Menu and enter the appropriate Base Year Methane Recovery Factor under the Methane Recovery Factor option on the Settings Menu. The software assumes a default Base Year Methane Recovery rate of zero. With these inputs, the software computes methane emissions using the methane commitment method. Based on the information you provide about the amount of waste, the waste management options employed, the composition of that waste, and the rate of methane recovery (if any) at the landfills, the software calculates the methane emissions that will eventually occur and assigns them to the active year, the year in which the waste was produced.

For the Other Sector: Enter emissions of greenhouse gases or air pollutants directly in the Other Emissions Inputs screen. This is a multi-record sector so you can make separate entries for each emissions source.

For All Sectors: Use the Notes Regarding... window to enter any information about this group that may help to better identify it. You can also use this space to note your data sources and contacts, or any other notes associated with the group.

There are also windows on some sector screens where you can enter Indicator Inputs. These are used to compute indicators of energy use, greenhouse gas emissions, and cost, such as energy use per square foot of floor area (for Buildings) or emissions per vehicle (for Vehicle Fleet) or energy costs per gallon processed (for Water and Sewage), etc. These indicators, which are output in the Indicators Report, serve as benchmarks that can help you to measure progress from year-to-year and to compare emissions in your operations with other local governments with similar operations. The current subtotals for the active sector are displayed in the Output Panel at the bottom of the window.

Finally, there is a Report button on each sector screen that opens up a dialog box containing a menu of the Government Analysis Report Options.

Emission Factors -- Average Grid Electricity

These emission factors specify the emissions per kilowatt-hour of the annual average kilowatt-hour produced in the electricity region specified. Default values are provided for 1990 through 2020. Essentially, these average kilowatt-hour factors have been derived by dividing emissions in each NERC region by end use electricity. Average grid electricity emission factors are recommended for use in developing your emissions inventory and quantifying emission reductions from electricity consumption reducing measures. The emissions generated from electricity use vary by season, day of the week and even by time of day. This variation is due to the fact that different electricity generating plants come on-stream to meet whatever the demand for electricity is at any given time. If your region uses nuclear, hydro-electric or renewable sources of electricity, they will be used to provide power 24 hours per day, seven days a week. During periods of low electricity demand, such as at night, these sources of electricity provide a greater share of total demand, reducing the emissions generated per kilowatt-hour during these times. However, during periods of peak demand, such as during the day, more expensive sources of electricity, such as natural gas, coal, or diesel combustion turbines will be used to meet the increased demand. The use of these sources of electricity increases the emissions generated per kilowatt-hour when they are in use.

Average grid electricity emission factors are the average of emissions generated per kilowatt-hour over an entire year, taking into account fuels used and generating and emission control technologies in use in each plant. Because it is difficult if not impossible for users of the Clean Air and Climate Protection Software to know when their electricity consumption occurred, the average grid electricity emission factors should be used in developing an inventory or in quantifying emission reductions from measures. These factors will provide the most accurate estimate of emissions generated from normal use of electricity. Marginal emission factors represent the emissions generated by the electricity source or sources used to produce the last kilowatt-hour of electricity demanded at any given time. These sources tend to be coal plants, natural gas and/or diesel-fired combustion turbines and the actual source may vary from one year to another. The marginal emission factors provided are the result of two changes, the effect on expansion of power supplies (the type, size and timing of new power plants) and the dispatch of the fleet of plants to meet loads.

Average marginal emission factors can differ substantially from average system emission factors. Marginal grid electricity emission factors are provided in the Clean Air and Climate Protection Software and can be used under certain circumstances for certain analytical purposes. They are NOT recommended for general use in creating inventories or quantifying emission reductions from measures. Generally, these emission factors would be used to demonstrate the impact of a specific measure on emissions, where the measure's impact on electricity demand (including when it influences demand) and supply is well understood. Emission factors for the inventory and measures analysis years 1990 and 1999 through 2020 were generated from the NEMS model for each region. However, NEMS data was not available for the years 1991 through 1998. For these years, emission factors were extrapolated from a straight-line mathematical formula from 1990 and 1999 data. The result is a fairly smooth set of emission factors for 1990 through 1999, but a higher degree of fluctuation in emission factors for 2000 through 2020, reflecting the assumptions contained with the NEMS model with regard to the future mix of generation sources in each region.

National average emission factors are also provided to support those users who do not wish to use region-specific values. For each pollutant, emission factors have been developed for all years for the 13 NERC regions.

WARNING: If you modify the emission coefficients, it will affect not only the specific record you may be working with, but ALL records that use the coefficient set. However, if you create a NEW coefficient set, you can select it for use with one or several specific records.

Regional average emission factors for carbon dioxide, sulfur dioxide, and nitrogen oxides were determined using a three-step process, as follows:

1. Total emissions (in short tons) of carbon dioxide, sulfur dioxide, and nitrogen oxides associated with electricity generation were obtained directly from regional outputs of the AEO2001 reference case NEMS model run.
2. Total electric sales of electricity (in MWh) were obtained directly from regional outputs of the AEO2001 reference case NEMS model run.
3. Final emission factors for each NERC region were determined by dividing total annual emissions by total annual electric sales.

Regional average emission factors for other criteria air pollutants including carbon monoxide, non-methane volatile organic compounds, and particular matter smaller than 10 microns in diameter were determined using a five-step process, as follows:

1. Emission inventory data was collected for the base year of 1999 at the national level from the U.S. EPA's National Air Quality and Emissions Trends Report (U.S. EPA, 2000)
2. Primary energy use data was collected by fuel type at the national level for the base year of 1999 from the outputs of the AEO2001 reference case NEMS model run.
3. Emission factors by fuel type were determined for the base year by dividing emissions (Step #1) by primary energy consumption (Step #2). This emission factor was assumed to be constant through the period 2000-2020.

4. Total annual, regional emissions for the years 2000-2020 were determined by multiplying the fuel based emission factors generated in Step #3 above by primary consumption of these fuels in each of the 13 NERC regions, as projected by the AEO2001 reference case NEMS model run.
5. Final annual emission factors for each NERC region were determined by dividing total annual emissions in Step #4 above by total annual electric sales, as projected by the AEO2001 reference case NEMS model run.

Regional average emission factors for methane (CH4) and nitrous oxide (N2O) were determined using a three-step process, as follows:

1. Since emission inventory levels for these pollutants are not tracked in the U.S. EPA's National Air Quality and Emissions Trends Report (U.S. EPA, 2000), we used "Tier 1" fuel-specific emission factors, as recommended by the Intergovernmental Panel on Climate Change (IPCC, 1996).
2. Total annual average emissions for the years 2000-2020 were determined by multiplying the fuel-based emission factors from Step #1 above by primary consumption of these fuels in each of the 13 NERC regions, as projected by the AEO2001 reference case NEMS model run.
3. Final annual emission factors for each NERC region were determined by dividing total annual emissions in Step #2 above by total annual electric sales, as projected by the AEO2001 reference case NEMS model run.

Emission Factors -- Marginal Grid Electricity

These emission factors specify the emissions per kilowatt-hour of the marginal source of electricity in the electricity region specified. Default values are provided for 1990 through 2020. Marginal emission factors represent the emissions generated by the electricity source or sources used to produce the last kilowatt-hour of electricity demanded at any given time. These sources tend to be coal plants, natural gas and/or diesel-fired combustion turbines and the actual source may vary from one year to another.

The marginal emission factors provided are the result of two changes, the effect on expansion of power supplies (the type, size and timing of new power plants) and the dispatch of the fleet of plants to meet loads. Average marginal emission factors can differ substantially from average system emission factors. Marginal grid electricity emission factors are provided in the Clean Air and Climate Protection Software and can be used under certain circumstances for certain analytical purposes. They are NOT recommended for general use in creating inventories or quantifying emission reductions from measures. Average grid electricity emission factors should be used instead.

Generally, marginal electricity emission factors would be used to demonstrate the impact of a specific measure on emissions, where the measure's impact on electricity demand (including when it influences demand) and supply is well understood. Users may notice substantial fluctuations in marginal emissions and/or emission factors from one year to the next in an electricity region. Very significant fluctuations in marginal emission factors from one year to the next occur because the NEMS model (see discussion below) used to create emission factors always assumes that the lowest cost source of electricity will be dispatched to meet the last kilowatt-hour of electricity demand.

Depending on the modeled demand for electricity for the electricity region in that year, this final dispatch source of electricity can be any one of a number of different generators using different fuels and firing technologies. In some cases, low emission generators of electricity will be taken off-line first if demand is reduced, which can result in an increase in emissions for the marginal, or last kilowatt-hour of electricity generated for that jurisdiction if the sources of electricity that remain on-line have higher emissions. In other cases, a high emission generator of electricity will be taken off-line if demand is reduced, resulting in lower emissions from marginal electricity generation if the electricity generators that remain on-line are less polluting. For these reasons, the marginal emission factor can vary a great deal from year to year.

While the significant fluctuations in marginal electricity emission factors occurs for years 2000-2020, it does not occur for years 1990 through 1999. The reason for this is that no model data was available for 1991 through 1999, and so the marginal electricity emission factors for these years were extrapolated from 1990 and 1999 emission factors. This has created a smooth distribution of marginal emission factors from year to year for this period.

WARNING: If you modify the emission coefficients, it will affect not only the specific record you may be working with, but ALL records that use the coefficient set. However, if you create a NEW coefficient set, you can select it for use with one or several specific records.

Regional average marginal emission factors for carbon dioxide, sulfur dioxide, and nitrogen oxides were determined using a three-step process, as follows:

1. The NEMS model was run with an electricity demand set slightly lower than the base case electricity demand. To reflect the situation where a city/region acts alone in its actions to decrease electricity consumption, the model was run with 1% decrease in electricity demand in one region at a time, while holding it constant in the remaining 12 regions (hereafter called the "NEMS 1% decrement run").
2. The change in the annual emission level in the region with decreased electricity consumption was determined by subtracting "decrement case" emission levels from reference case emission levels.
3. The marginal emission factor was determined as the change in the annual emission level divided by the change in annual electricity generation, as projected by the NEMS 1% decrement run.

Regional average marginal emission factors for other criteria air pollutants including carbon monoxide, non-methane volatile organic compounds, and particular matter smaller than 10 microns in diameter were determined using a five-step process, as follows:

1. The change in annual primary fuel use by type was determined by subtracting fuel consumption levels in the NEMS 1% decrement run from fuel consumption levels from reference case fuel consumption levels.
2. Total annual, marginal emissions for the years 2000-2020 were determined by multiplying fuel-specific average system emission factors by the change in annual primary consumption of these fuels in each of the 13 NERC regions, as projected by the NEMS 1% decrement run.
3. Annual marginal emission factors for each NERC region were determined by dividing total annual marginal emissions in Step #2 above by the change in annual electricity generation, as projected by the NEMS 1% decrement run.

Regional average marginal emission factors for methane (CH_4) and nitrous oxide (N_2O) were determined using a three-step process, as follows:

1. The change in annual primary fuel use by type was determined by subtracting fuel consumption levels in the NEMS 1% decrement run from fuel consumption levels from reference case fuel consumption levels.
2. Total annual, marginal emissions for the years 2000-2020 were determined by multiplying fuel-specific average system emission factors by the change in annual primary consumption of these fuels in each of the 13 NERC regions, as projected by the NEMS 1% decrement run.
3. Annual marginal emission factors for each NERC region were determined by dividing total annual marginal emissions in Step #2 above by the change in annual electricity generation, as projected by the NEMS 1% decrement run.

Table E1
Northeast Power Coordinating Council/New England Grid Electricity Coefficients

	Abbre-viation	tons CO_2e/GWh	
		Avg	Marginal
Carbon Dioxide	CO_2	345	718.8
Nitrous Oxide	N_2O	0.068	0.000
Methane	CH_4	0.056	0.011
Nitrogen Oxides	NO_x	0.314	0.278
Sulfur Oxides	SO_x	0.541	-1.191
Carbon Monoxide	CO	0.626	0.336
Volitile Organic Compounds	VOC	0.069	0.026
Particulates <10nm	PM_{10}	0.471	-0.024

Table E2
Carbon Equivalents by Electricity Generation Fuel

	lb CO_2e/kWh
Anthracite Electricity	2.723
Bituminous Electricity	2.458
Coke Electricity	3.001
Lignite Electricity	2.579
Subbituminous Electricity	2.547
Natural Gas Electricity	1.472
Propane Electricity	1.729
Heavy Fuel Oil Electricity	2.186
Light Fuel Oil Electricity	1.966
Wood (Freshly Cut) Electricity	0.000
Wood (Oven Dry) Electricity	0.000

Energy Densities

To be represented in the software in natural units (e.g. gallons, cubic feet, tons) the energy density of each fuel must be specified. Once the energy density of a fuel is defined, then the ratios used to covert between various natural and physical units can be computed. There are three sets of natural energy units maintained in the software – for weight, volume and gas densities. In general, the weight densities are for solid fuels, the volume densities are for liquid fuels and the gas densities are for gaseous fuels. However, a fuel may have more than one type of density defined (e.g. fuel oil has both a weight and a volume density). In terms of the software, the setting of a density value for a fuel determines the types of units that are available for that fuel. The fuel types have been selected and defined based on a review of US commodity tables.

Fuel Energy Densities The table below indicates the default energy densities employed in the software, in GJ per liter for liquid fuels, GJ per ton for solid fuels, and GJ per cubic meter for gaseous fuels.

Energy Density Data Sources The sources for the energy densities used within the U.S. Version 5.0 CCP are presented below. For each fuel considered in the software, U.S. sources were consulted. However, for a number of fuels, specifically the more obscure fuels, international defaults taken from the 1996 IPCC Reporting Guidelines on Greenhouse Gas Emissions were used.

Solid Fuels: For all coals excluding peat, energy intensities were taken from the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990:1998 (EPA, 2000). The energy density for peat was based on the international default as suggested by the IPCC (1996).

Liquid Fuels The following fuel energy densities included in version 5.0 of the U.S. CCP are based on the US EPA (2000): Motor gasoline, kerosene, jet fuel, light fuel oil, heavy fuel oil, ethanol mixes, etc. The EPA (2000) give a variety of density conversions factors, allowing for the conversions of the various fuels between the various liquid, gaseous, and weight densities that were required for inclusion in the US CCP tool. There were no identifiable US governmental sources for the energy density of liquid petroleum gas and for diesel. For these fuels, the energy densities were taken from the OECD Conversions and Calorific Values databases supplied by the International Environment Agency.

Gaseous Fuels There are a number of fuels where energy densities were provided on an energy density per gaseous unit (cubic meter of gas) within the US CCP; natural gas, compressed natural gas, and hydrogen. The natural gas and compressed natural gas energy densities were extracted from the EPA (2000), while the hydrogen energy density was taken from prior research completed at Torrie Smith Associates.

Energy Densities Extracted from the IPCC The following fuel energy densities were taken directly from the international defaults provided by the IPPC (1996): Peat, charcoal, wood (freshly cut), wood (oven dried), MSW, refuse derived fuel, agricultural waste, bagasse, and dung.

Additional Notes on Specific Fuels

Compressed Natural Gas. There is both a "per Gallon" and a "per cubic foot" energy density provided for this fuel, although it is not in a liquid state when compressed. Users should use gallons when quantifying CNG in its compressed form (200 atmospheres) and cubic feet when quantifying it in its uncompressed form.

Renewable Fuels. Renewable energy includes solar power, wind, wave and tide, hydroelectricity, renewable biofuels, and renewable solid fuels.

Ethanol. Ethyl Alcohol or Grain Alcohol (CH3CH2OH) is a high octane, water-free alcohol that is produced chemically from ethylene or biologically from the fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues from crops or wood. It is commonly used as an octane enhancer in gasoline and as an oxygenate, it increases octane 2.5 to 3.0 numbers at 10% concentration (E-10). It is traditionally used as a blending ingredient at 10% concentrations (termed E-10) in gasoline or as a raw material to produce high-octane fuel ether additives. Automobiles, unless specially outfitted with a specialized engine, can only burn a mix that is 10% ethanol and 90% gasoline, although a number of manufacturers are now producing automobiles that can run on 85% ethanol (E-85). The default energy density values for the ethanol fuels are based on an energy density for pure ethanol of 26.8 MJ/kg (from Hayden, University of Connecticut, www.energyadvocate.com/we_are.htm). In comparison to gasoline (motor-spirit), ethanol has about two-thirds of the energy density. The lower energy density means that a pure-alcohol-fueled vehicle would reduce the mileage gained from the same volume of regular gasoline by one half to two-thirds. However, these energy density differences are compensated for somewhat by improvements in efficiency that can be realized in spark ignition engines using alcohol compared with gasoline. E-85 (85% ethanol, 15 % gasoline by content) has higher energy densities than neat ethanol because of the addition of gasoline.

Green Electricity. This term refers to wind, solar, tidal, wave power, small hydro, and any other form of zero emission electricity. Electricity made from biomass burning is green insofar as carbon dioxide emissions are concerned, but emission factors should be defined for the other pollutants from biomass burning.

Coal. There are five types of coal specified in the software's default fuel list, plus a generic "Coal" fuel that is based on a weighted average of the factors for anthracite, bituminous, sub-bituminous, and lignite coals. The individual coal types, which constitute the generalized coal, each have their coefficients separately defined in the software.

District Energy. This refers to heat produced at central plants, usually in combination with power production. A 25-35% reduction in primary fuel use can be obtained as compared with electricity-only generation and heat-only boilers, allowing the host organizations to make a substantial savings in costs and emissions.

Emission Factors for Residential, Commercial and Industrial Energy Use -- Average Technology

These emissions factors represent the typical emissions of air pollutants associated with the burning of the fuels listed. In some cases, the emission factors vary by sector (e.g. emissions for fuel oil are different in the industrial than the residential sector). These average emission factors can be used as defaults throughout the residential, commercial and industrial sectors for both inventory and measures analysis, and they are recommended for use in the analysis modules. WARNING: If you modify the emission coefficients, it will affect not only the specific record you may be working with, but ALL records that use the coefficient set. However, if you create a NEW coefficient set, you can select it for use with one or several specific records.

Further Details of the research provided by the Tellus Institute in the development of the CACP software emission factors

Sources There are several sources used to develop RCI emission factors:

1. Criteria air pollutant emissions levels are from the USEPA's annual report of air pollution emission trends (USEPA, 2001c). Specialized reports from this database are developed from USEPA (2001b).
2. Fuel consumption for 1990: National Energy Modeling System (NEMS) internal data (USEIA, 2001a).
3. Fuel consumption for the years 1999 through 2020: National Energy Modeling System (NEMS) output for the reference case (USEIA, 2001).
4. Greenhouse gas emission factors by fuel type are taken from IPCC, 1996.

Assumptions

1. The EPA and EIA use the same classification guidelines to determine sector-based characteristics (i.e. the two databases define which energy uses and correlated emissions fall into "residential," "commercial," and "industrial" sectors in the same manner).
2. Emission factors calculated for 1999 are presumed to hold true through 2020.

Baseline (1990, 1999-2020) Emission Factors

CO, NOx, VOC, SO2, PM10: lb/MMbtu Emission factors for the above pollutants were determined for the years 1999 through 2020 by fuel and sector using a three-step process, as outlined below:

1. Obtain total emissions by sector and fuel type from USEPA (2001b) for the years 1990 and 1999.
2. Obtain energy consumption data by sector and fuel type from USEIA (2001a) for 1990.
3. Obtain energy consumption data by sector and fuel type from USEIA (2001) for 1999.

4. For 1990 and 1999 emission factors, divide emissions by fuel use.
5. For 2000 through 2020 emission factors, use the 1999 value.

Note: emission factors for the residential sector for natural gas and oil for CO, VOCs, and PM10 were set equal to commercial sector emission factors due to a lack of specification in the pollutant emission data.

CO2, CH4, and N2O: lb/mmbtu IPCC (1996) GHG emission factors for each sector were converted from units of kg/TJ to lb/mmbtu and applied to 1990 and 1999 through 2020.

Emission Factors for Residential, Commercial and Industrial Energy Use

These emission factors specify emissions of criteria air pollutants for a variety of combinations of fuels and combustion technologies and control technologies. Measures in these demand sectors are likely to be either efficiency-based (e.g., a more efficient boiler in the industrial sector), fuel switching (e.g., replacing an oil furnace with a natural gas furnace in the residential sector), or pollution control based (e.g., adding a scrubber to a coal steam power station). The first two measures (i.e., efficiency and fuel switching) will result in changes in emissions that are due only to the type and quantify of fuel being used, whereas the changes in emissions from the third measure depend on combustion and control technologies employed.

This section describes the sources, assumptions, and methods to determine the emission factors of RCI (residential, commercial, industrial) technologies subject to a range of pollution control equipment. For more information on specific combustion technologies, visit the United States Environmental Protection Agency's Technology Transfer Network for information from its Compilation of Air Pollution Emission Factors (AP-42) manual. AP-42 is the authoritative source of information with respect to emission factors, fuels and combustion technologies and has been extensively used in the development of emission factors for the Clean Air and Climate Protection Software. It provides up-to-date information on air pollution emission factors in non-technical language. WARNING: If you modify the emission coefficients, it will affect not only the specific record you may be working with, but ALL records that use the coefficient set. However, if you create a NEW coefficient set, you can select it for use with one or several specific records.

Sources A variety of sources used in the determination of emission factors:

1. Emission Factors were obtained from USEPA (2001f)
2. Fuel specifications were obtained from USEPA (2001f). For those fuels not included in the AP-42 Appendix, values from the LEAP model program were used.
3. Low-Sulfur Coal data was obtained from a number of sources from the USEIA (2001b) USEIA (low-sulfur coal forms), FERC (2001), the US Department of Commerce (2001), and Hong and Slater (1995).
4. CH4 and N2O emission factors are provided from ICF (1999), IPCC (1994) and De Soete (1993).

Assumptions

1. Most values come from directly or are derived from the EPA Compilation of Air Pollutant Emission Factors (AP-42). Preference is given to AP-42 values over other data sources.
2. The processes that control pollutant emissions are described and quantified in the text and tables within AP-42. Values for pollution control efficiency relative uncontrolled emission factors were assumed to be representative.
3. Not all fuels have data for each process. We have assumed that these categories are not applicable.
4. The USEPA's AP-42 database is given precedence over the IPCC values. For some process/fuel combinations, AP-42 provides N2O and/or CH4 emission factors. For those that the AP-42 does not cover, the IPCC values are used. Converting from the generic "coal" emission factor for nitrous oxide (as given by IPCC) to specific

types of coal, it was assumed that nitrous oxide emissions would be relative to the percentage nitrogen content in the fuel.

5. It is assumed that the controls do not change N2O or CH4 emissions, due to the lack of available data and lack of actual influence, respectively.

NOx, VOC, PM-10, SO2, and CO Emission factors There are several generalized steps for calculating these emission factors:

1. Obtain uncontrolled emission factors: Uncontrolled process emission factors are taken directly from the EPA's AP-42 FIRE database.
2. Convert to units of lb per mmbtu: Emission factors from the FIRE database are provided in units of pounds per ton. To convert to pounds per mmbtu, the emission factor was divided by the heating value (mmbtu/ton) of the fuel.
3. Split emission factors into two groups: coal and non-coal fuels. These groups are described in the next subsections, along with the case of low-sulfur coal.
4. Determine controlled Emission Factors: Emission factors for processes with emission controls were provided in one of two ways.
   - Provided: If emission factors for the controls are provided by AP-42 or in the FIRE database, then these are used.
   - Calculated: The FIRE database does not provide factors for every control for each process and fuel type, so in some cases controlled emission factors needed to be calculated. Based on descriptions of the control types in the text and tables within the AP-42 document, control efficiency values can be determined (for example, electrostatic precipitators (ESP's) are 97.7% effective at reducing particulate matter). These efficiency values were used to calculate controlled emission factors as a reduction in emissions relative to the uncontrolled case for the pollutant in question. Pollutants not affected by the control technologies have the same emission factors as in the uncontrolled case. Most controls are measures applied to the boiler itself, and are described within the AP-42 document. Efficiency values for particulate matter were derived from tables showing size specific emission factors for different control types. Values for particle size 10 µm were compared for each control against the uncontrolled factor to find the control efficiency.

Coal Fuels Coal fuels used in industrial boilers have potentially four specific types of scrubbers that could be used to control SO2 (lime/limestone, dual alkali, magnesium oxide/hydroxide, and sodium carbonate), as well as a generic label "scrubbers". Each of these scrubber-types was assigned a value for controlling PM10 as well as SO2. The other controls affect the emission factors of only one pollutant (i.e. ESP's, baghouses, and multiple cyclones control PM10 emissions; low NOx burners (LNB), overfire air (OFA), reburning, selective catalytic reduction (SCR), and selective non-catalytic reduction (SNCR) control NOx emissions).

Low Sulfur Coal As with the electric sector, a fuel-based, rather than control equipment-based approach to achieving sulfur emission reductions is the use of low sulfur coal. Rather than being a change made to the boiler facility, low sulfur coal has a different chemical content, and could be subject to additional controls (most likely for other emissions such as NOx or PM10). This fuel type was determined in two steps:

1. The emission factors (in lb/ton) for this type of coal were taken as the average of the values for bituminous and sub-bituminous coal for each of the different boiler types.
2. These were converted to factors with units of lb/mmbtu using a heating value of 19.43 mmbtu/ton, which is derived from data from the Energy Information Administration (1995). The sulfur value of this coal (0.3 lb S/mmbtu coal) is also taken from the Energy Information Administration (2001).

Because the low sulfur coal emission factors are averages, values for each pollutant will be different from the uncontrolled case using a fuel with normal sulfur content. To apply additional controls to this coal, the sulfur value should be taken from this fuel and the controlled pollutant should be taken from the normal-fuel case.

Non-Coal Fuels Non-coal fuels for the RCI sectors include natural gas, oil, and biomass. These fuels have different controls from coal, primarily focusing on NOx rather than SOx emissions. Fuel oils (distillate oil and residual oil) have a large number of control options. Their NOx emissions can be controlled to varying degrees by the following types of pollution control technologies:

- Flue gas recirculation (FGR)
- Burners out of service (BOOS)
- Selective non-catalytic reduction (SNCR)
- Selective catalytic reduction (SCR)
- Low excess air (LEA)
- Staged combustion (SC)
- FGR + SC
- Reduced Air Preheat (RAP)
- Air Heater (SCR)
- Duct SCR
- Low NOx burners (LNB) and FGR Particulate matter control technologies are the same as for coal (i.e. cyclones, ESP, and baghouse filters) and there is also a single scrubber option that controls both PM10 and SOx emissions.

CO2, CH4, and N2O Emission factors These emission factors are determined in two steps:

1. Obtain uncontrolled emission factors: Uncontrolled process emission factors are taken directly from the EPA's AP-42 FIRE database, where possible.
2. Convert to units of lb per mmbtu: Emission factors from the FIRE database are provided in units of pounds per ton. To convert to pounds per mmbtu, the emission factor was divided by the heating value (mmbtu/ton) of the fuel.

Use IPCC data for missing data: Process/fuel combinations not represented in AP42 apply IPCC data, adjusted according to the particular fuel’s nitrogen content. Measures in the electric sectors are likely to be either efficiency-based (e.g., a more efficient prime mover), fuel switching (e.g., switching from oil to natural gas), or pollution control based (e.g., adding a scrubber to a coal steam power station). The first two measures (i.e., efficiency and fuel switching) will result in changes in emissions that can be tracked using the baseline-based emission factors. However, the last measure (i.e., pollution control) will lead to significant variation in air pollution emission factors. This section describes the sources, assumptions, and methods to determine the emission factors of electric generation facilities subject to a range of pollution control equipment.

Sources A variety of sources used in the determination of emission factors:

1. Emission Factors were obtained from USEPA (2001f)
2. Fuel specifications were obtained from USEPA (2001f). For those fuels not included in the AP-42 Appendix, values from the LEAP model program were used.
3. Low-Sulfur Coal data was obtained from a number of sources from the USEIA (2001b) USEIA (low-sulfur coal forms), FERC (2001), the US Department of Commerce (2001), and Hong and Slater (1995).
4. CH4 and N2O emission factors are provided from ICF (1999), IPCC (1994) and De Soete (1993).

Assumptions

1. Most values come from directly or are derived from the EPA Compilation of Air Pollutant Emission Factors (AP-42). Preference is given to AP-42 values over other data sources.
2. The processes that control pollutant emissions are described and quantified in the text and tables within AP-42. Values for pollution control efficiency relative uncontrolled emission factors were assumed to be representative.
3. Not all fuels have data for each process (e.g. anthracite and coke have no data available for AFBC boiler types). We have assumed that these categories are not applicable.
4. The USEPA's AP-42 database is given precedence over the IPCC values. For some process/fuel combinations, AP-42 provides N2O and/or CH4 emission factors. For those that the AP-42 does not cover, the IPCC values are used. Converting from the generic "coal" emission factor for nitrous oxide (as given by IPCC) to specific types of coal, it was assumed that nitrous oxide emissions would be relative to the percentage nitrogen content in the fuel.
5. It is assumed that the controls do not change N2O or CH4 emissions, due to the lack of available data and lack of actual influence, respectively.

NOx, VOC, PM-10, SO2, and CO Emission factors. There are several generalized steps for calculating these emission factors:

1. Obtain uncontrolled emission factors: Uncontrolled process emission factors are taken directly from the EPA's AP-42 FIRE database.
2. Convert to units of lb per mmbtu: Emission factors from the FIRE database are provided in units of pounds per ton. To convert to pounds per mmbtu, the emission factor was divided by the heating value (mmbtu/ton) of the fuel.
3. Split emission factors into two groups: coal and non-coal fuels. These groups are described in the next subsections, along with the case of low-sulfur coal.
4. Determine controlled Emission Factors: Emission factors for processes with emission controls were provided in one of two ways.
   - Provided: If emission factors for the controls are provided by AP-42 or in the FIRE database, then these are used.
   - Calculated: The FIRE database does not provide factors for every control for each process and fuel type, so in some cases controlled emission factors needed to be calculated. Based on descriptions of the control types in the text and tables within the AP-42 document, control efficiency values can be determined (for example, electrostatic precipitators (ESP's) are 97.7% effective at reducing particulate matter). These efficiency values were used to calculate controlled emission factors as a reduction in emissions relative to the uncontrolled case for the pollutant in question. Pollutants not affected by the control technologies have the same emission factors as in the uncontrolled case. Most controls are measures applied to the boiler itself, and are described within the AP-42 document. Efficiency values for particulate matter were derived from tables showing size specific emission factors for different control types. Values for particle size 10 µm were compared for each control against the uncontrolled factor to find the control efficiency.

Coal Fuels Coal fuels have four specific types of scrubbers used to control SO2 (lime/limestone, dual alkali, magnesium oxide/hydroxide, and sodium carbonate), as well as a generic label "scrubbers". Each of these scrubber-types was assigned a value for controlling PM10 as well as SO2. The other controls affect the emission factors of only one pollutant (i.e. ESP's, baghouses, and multiple cyclones control PM10 emissions; low NOx burners (LNB), overfire air (OFA), reburning, selective catalytic reduction (SCR), and selective non-catalytic reduction (SNCR) control NOx emissions).

Low Sulfur Coal A fuel-based, rather than control equipment-based approach to achieving sulfur emission reductions is the use of low sulfur coal. Rather than being a change made to the boiler facility, low sulfur coal has a different chemical content, and could be subject to additional controls (most likely for other emissions such as NOx or PM10). This fuel type was determined in two steps:

1. The emission factors (in lb/ton) for this type of coal were taken as the average of the values for bituminous and sub-bituminous coal for each of the different boiler types.
2. These were converted to factors with units of lb/mmbtu using a heating value of 19.43 mmbtu/ton, which is derived from data from the Energy Information Administration (1995). The sulfur value of this coal (0.3 lb S/mmbtu coal) is also taken from the Energy Information Administration (2001).

Because the low sulfur coal emission factors are averages, values for each pollutant will be different from the uncontrolled case using a fuel with normal sulfur content. To apply additional controls to this coal, the sulfur value should be taken from this fuel and the controlled pollutant should be taken from the normal-fuel case.

Non-Coal Fuels Non-coal fuels include natural gas, oil, and biomass. These fuels have different controls from coal, primarily focusing on NOx rather than SOx emissions. Fuel oils (distillate oil and residual oil) have a large number of control options.

Fuel Oil Particulate matter control technologies are the same as for coal (i.e. cyclones, ESP, and baghouse filters) and there is also a single scrubber option that controls both PM10 and SOx emissions. The midrange value is a calculated simple average, and was used to represent average emission factors from the implementation of these technologies. For the LNB and FGR category, the average value is as specified in AP42. Values for specific fuel oil grades (e.g. distillate oil grade 4; distillate oil grades 1 and 2; residual oil grade 5; and residual oil grade 6), computed using the control efficiencies provided below, are also provided when possible (i.e., uncontrolled emission factors estimates provided in AP42).

Natural gas, a generally clean-burning fuel with negligible PM10 and SOx emissions, applies controls equipment only for the reduction in NOx emissions, as well as nitrous oxide emissions. The types are control equipment include low NOx burners, selective non-catalytic reduction, selective catalytic reduction, and flue-gas recirculation.

CO2, CH4, and N2O Emission factors These emission factors are determined in two steps:

1. Obtain uncontrolled emission factors: Uncontrolled process emission factors are taken directly from the EPA's AP-42 FIRE database, where possible.
2. Convert to units of lb per mmbtu: Emission factors from the FIRE database are provided in units of pounds per ton. To convert to pounds per mmbtu, the emission factor was divided by the heating value (mmbtu/ton) of the fuel.

Use IPCC data for missing data: Process/fuel combinations not represented in AP42 apply IPCC data, adjusted according to the particular fuel’s nitrogen content.

Table E3

Carbon Generation by Fuel

	lb CO_2e/MMBtu
Heavy Fuel Oil	183.012
Kerosene	167.839
Light Fuel Oil	164.408
Natural Gas	123.248
Propane	144.642
Stationary Diesel	171.850
Stationary Gasoline	164.873
Coal	215.568
Anthracite	227.893
Bituminous	205.569
Coke	251.147
Lignite	215.800
Subbituminous	213.010
Peat	246.031
Agricultural Waste	0.000
Biomethane	0.000
Charcoal	0.000
Fuelwood (Air Dry)	0.000
Heat Plants	0.000
Landfill Methane	0.000
MSW	0.000
Refuse Derived Fuel	0.000
Sewage Gas	0.000
Solar	0.000
Wood (Freshly Cut)	0.000
Wood (Oven Dry)	0.000
Green Electricity	0.000
Landfill Gas Electricity	0.000
Biodiesel (B-20)	123.800
Biodiesel (B-100)	0.000
CNG	123.248
Diesel	171.850
Diesel (ULSD)	154.802
Ehtanol (E-10)	148.386
Ethanol (E-85)	24.731
Ethanol (E-100)	0.000
Ethanol-Diesel	158.686
Gasoline	164.873
Hydrogen	147.200
LPG	144.642
Methanol (M-85)	139.991

Table E4
Carbon Equivalents by Fuel and Sector

	lb CO_2e/MMBtu						
	N_2O	CH_4	NO_x	SO_x	CO	VOC	PM_{10}
Coal, Commercial	0.003	0.230	1.109	5.936	0.451	0.028	0.520
Coal, Industrial	0.003	0.230	0.622	1.507	0.126	0.008	0.085
Coal, Residential	0.003	0.230	1.109	5.936	0.451	0.028	0.520
Heavy Fuel Oil, Industrial	0.001	0.007	0.911	4.323	0.479	0.077	0.261
Kerosene	0.001	0.023	0.265	0.826	0.054	0.009	0.032
Light Fuel Oil, Commercial	0.001	0.023	0.265	0.826	0.054	0.009	0.032
Light Fuel Oil, Industrial	0.001	0.005	0.148	0.321	0.511	0.105	0.011
Light Fuel Oil, Residential	0.001	0.023	0.264	0.147	0.054	0.009	0.032
Natural Gas, Commercial	0.000	0.012	0.168	0.007	0.043	0.009	0.005
Natural Gas, Industrial	0.000	0.012	0.294	0.141	0.083	0.015	0.010
Natural Gas, Residential	0.000	0.012	0.176	0.007	0.043	0.009	0.005
Propane, Commercial	0.000	0.002	0.153	0.000	0.021	0.005	0.004
Propane, Industrial	0.000	0.002	0.208	0.000	0.035	0.005	0.007
Propane, Residential	0.000	0.002	0.153	0.000	0.021	0.005	0.004
Stationary Diesel	0.005	0.007	4.410	0.290	0.950	0.350	0.310
Stationary Gasoline, Industrial	0.012	0.018	1.630	0.084	62.700	2.100	0.100
Agricultural Waste	2.883	14.650	0.233	0.093	11.627	1.395	0.330
Biomethane	0.000	0.000	0.000	0.000	0.000	0.000	0.010
Charcoal	2.883	9.767	0.233	0.000	16.278	0.233	0.520
Fuelwood (Air Dry)	0.009	0.697	0.100	0.014	8.129	1.498	1.060
Heat Plants	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Landfill Methane	0.000	0.000	0.000	0.000	0.000	0.000	0.010
MSW	2.883	14.650	0.233	0.009	11.627	1.395	0.330
Peat	1.009	8.247	0.425	3.332	2.868	0.292	0.330
Refuse Derived Fuel	2.883	14.650	0.233	0.009	11.627	1.395	0.330
Sewage Gas	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Solar	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wood (Freshly Cut)	0.009	0.021	0.490	0.025	0.600	0.038	0.330
Wood (Oven Dry)	0.009	0.021	0.220	0.025	0.600	0.038	0.400
Green Electricity	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Landfill Gas Electricity	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Emission Factors for Transportation

Equivalent CO_2 tons for transportation was provided by the Commonwealth's Office of Central Planning for the town-wide analysis. This information was entered into the software directly rather than entering miles traveled or fuel consumption. GHG equivalent tons for the town fleet is calculated automatically per historical fuel volumes. Please contact the committee to receive additional calculation information.

Emission Factors -- Waste Management

These are the factors that are used to characterize waste-related emissions of greenhouse gases. The CACP software does not yet support quantification of criteria pollutant emission reductions from waste reduction and recycling initiatives but the upstream carbon dioxide emission savings from reduction and recycling are included in the coefficients, along with landfill and forestry sequestration impacts. Further details are provided in the Waste Primer Help topic. WARNING: If you modify the emission coefficients, it will affect not only the specific record you may be working with, but ALL records that use the coefficient set. However, if you create a NEW coefficient set, you can select it for use with one or several specific records.

Table E5
Carbon Equivalents by Fuel and Sector

	lb CO_2e/ton of Waste	
	Methane CH4	Site Sequester
Paper Products	4,276.526	-1,855.851
Food Waste	2,420.675	-161.378
Plant Debris	1,371.716	-1,694.472
Wood/Textiles	1,210.337	-1,694.472
All Other Waste	0.000	0.000

Appendix F: GHG Emissions Calculation Inputs and Results

The following screenshots document the inputs used to develop the GHG emissions values included in the report. Output pages are included as well.

Table F1
Community Residential Inputs

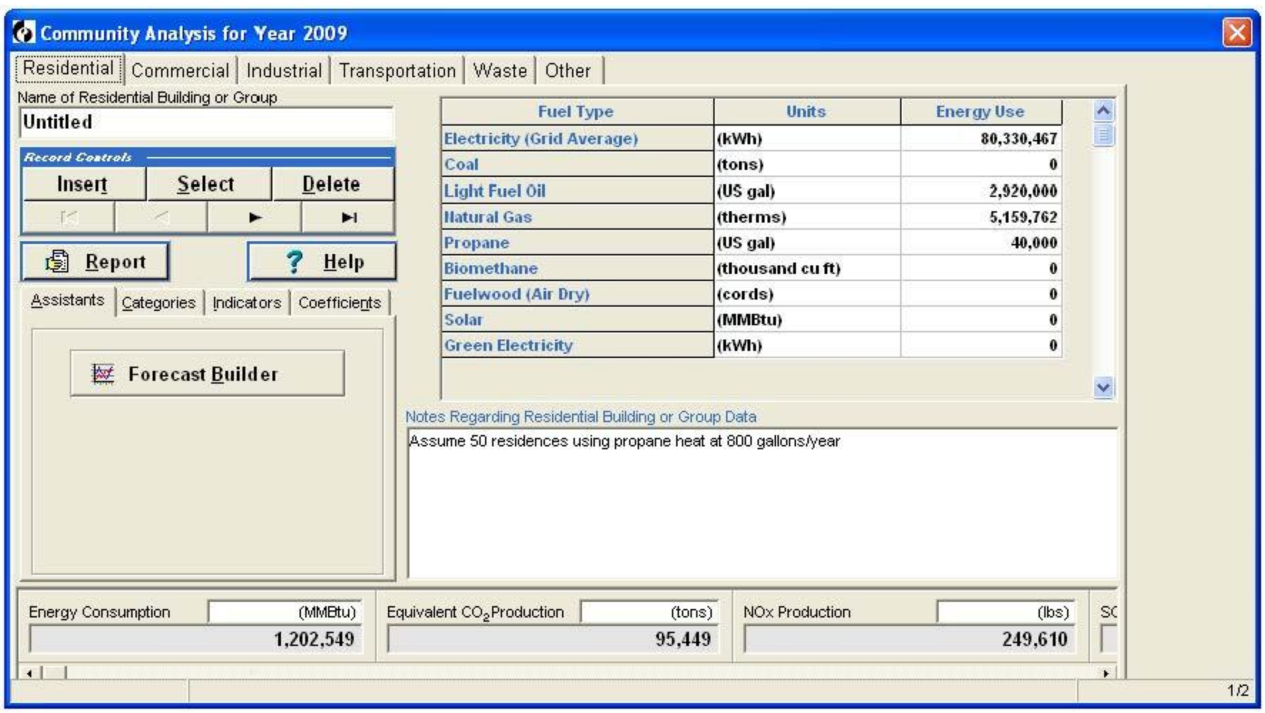
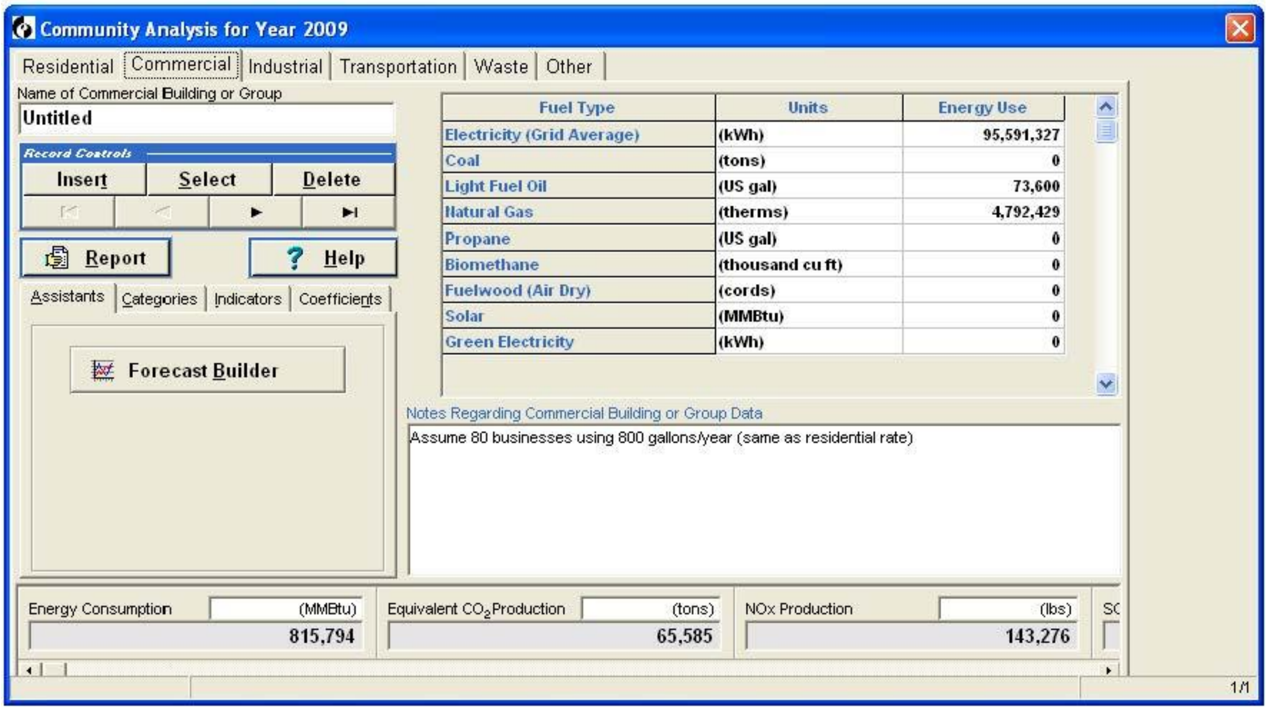
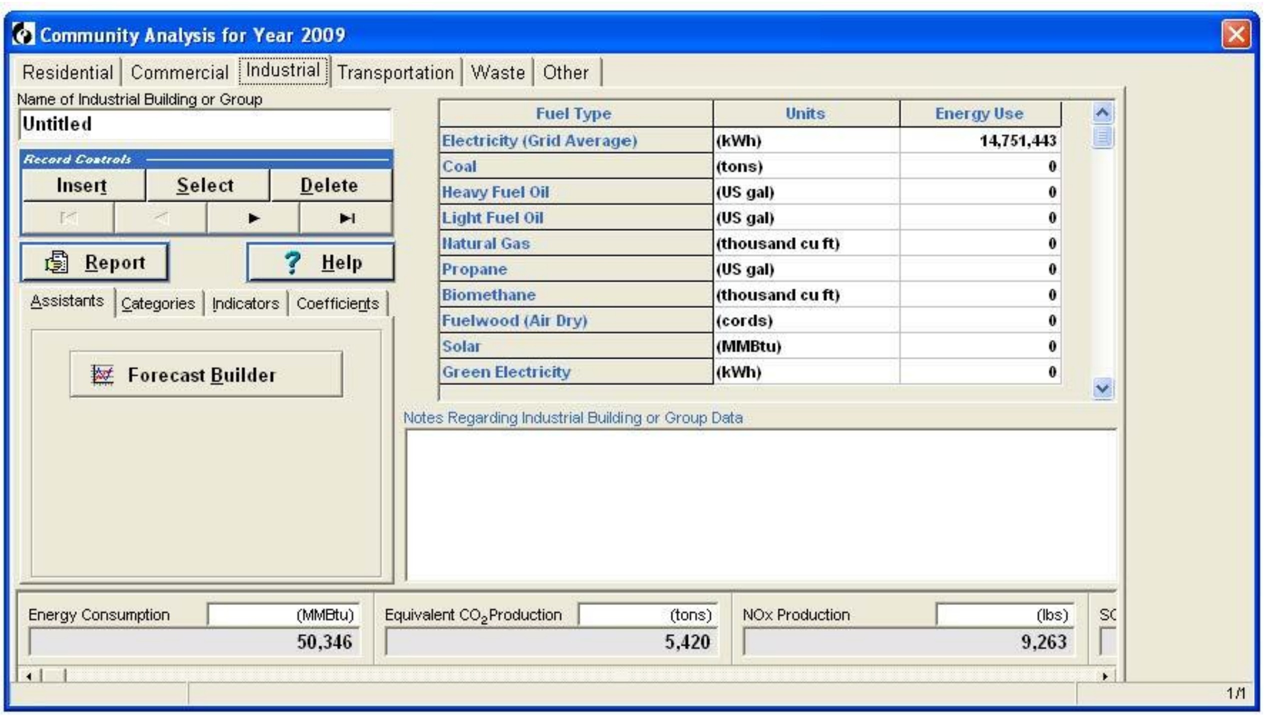


Table F2
Community Commercial Inputs



Fuel Type	Units	Energy Use
Electricity (Grid Average)	(kWh)	95,591,327
Coal	(tons)	0
Light Fuel Oil	(US gal)	73,600
Natural Gas	(therms)	4,792,429
Propane	(US gal)	0
Biomethane	(thousand cu ft)	0
Fuelwood (Air Dry)	(cords)	0
Solar	(MMBtu)	0
Green Electricity	(kWh)	0

Table F3
Community Industrial Inputs



Fuel Type	Units	Energy Use
Electricity (Grid Average)	(kWh)	14,751,443
Coal	(tons)	0
Heavy Fuel Oil	(US gal)	0
Light Fuel Oil	(US gal)	0
Natural Gas	(thousand cu ft)	0
Propane	(US gal)	0
Biomethane	(thousand cu ft)	0
Fuelwood (Air Dry)	(cords)	0
Solar	(MMBtu)	0
Green Electricity	(kWh)	0

Table F4

Community Transportation Inputs

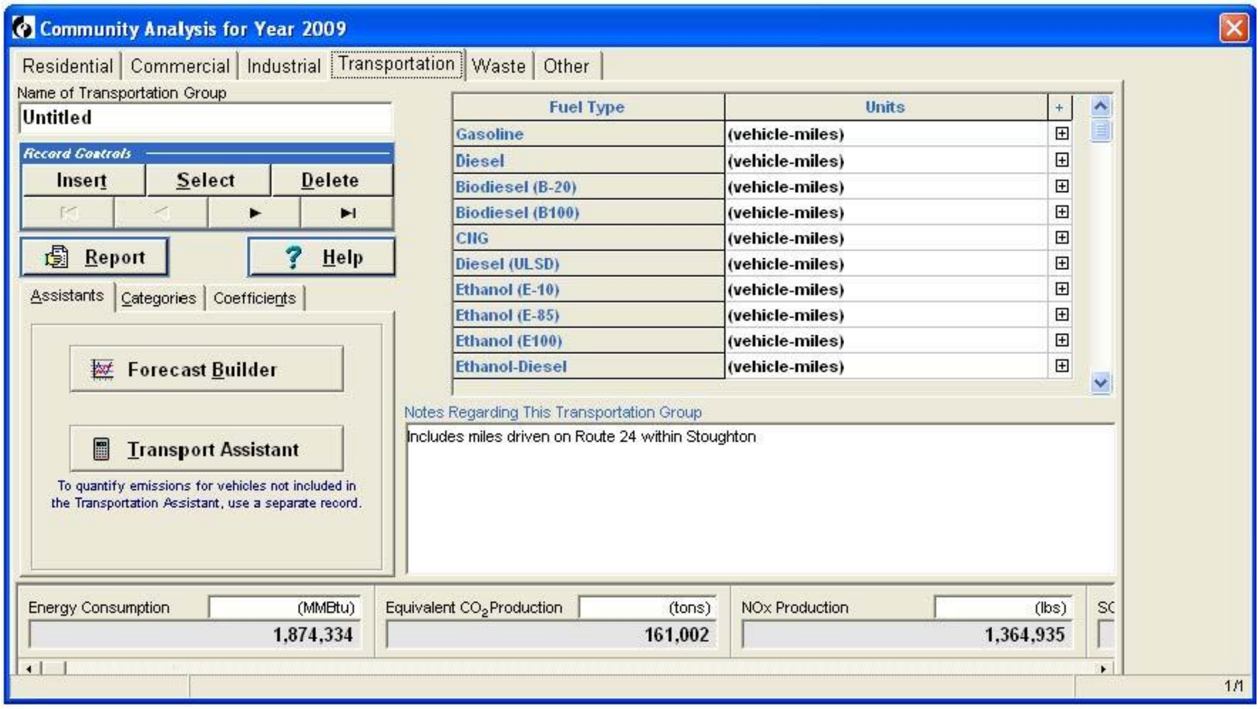


Table F5

Community Composted Waste Inputs

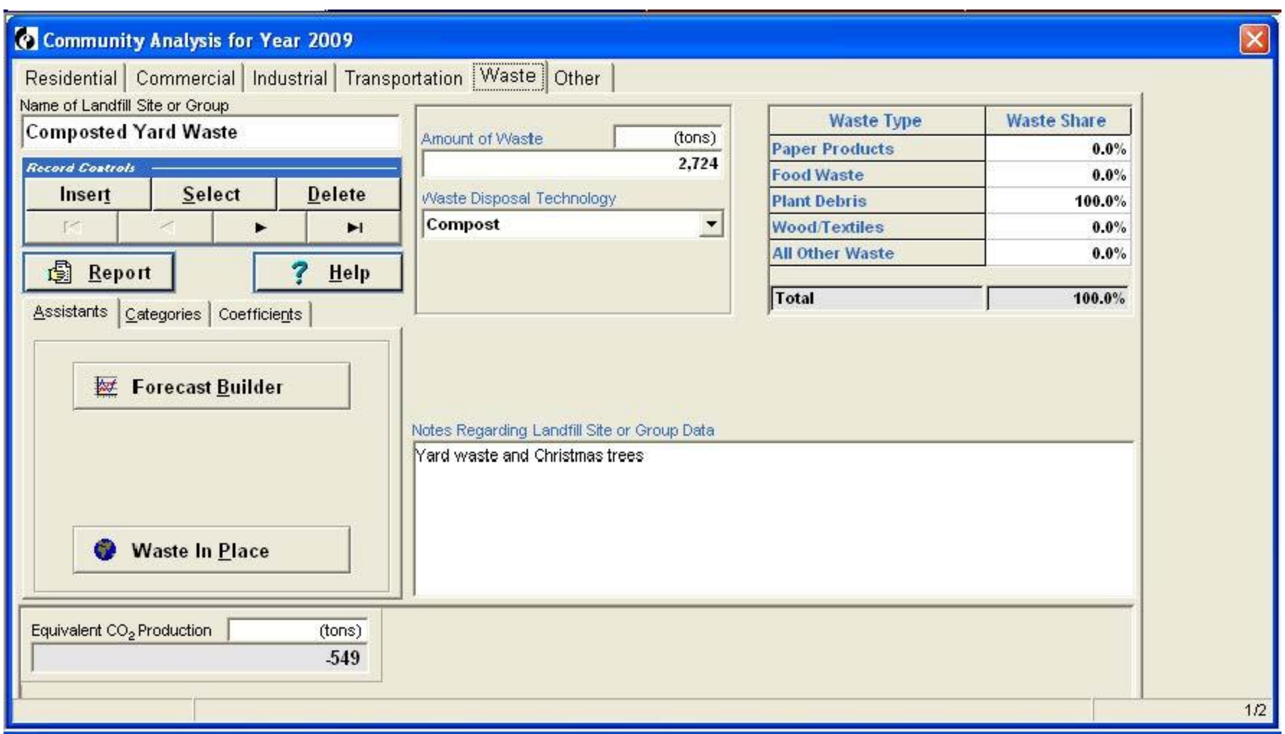


Table F6
Community Solid Waste Inputs

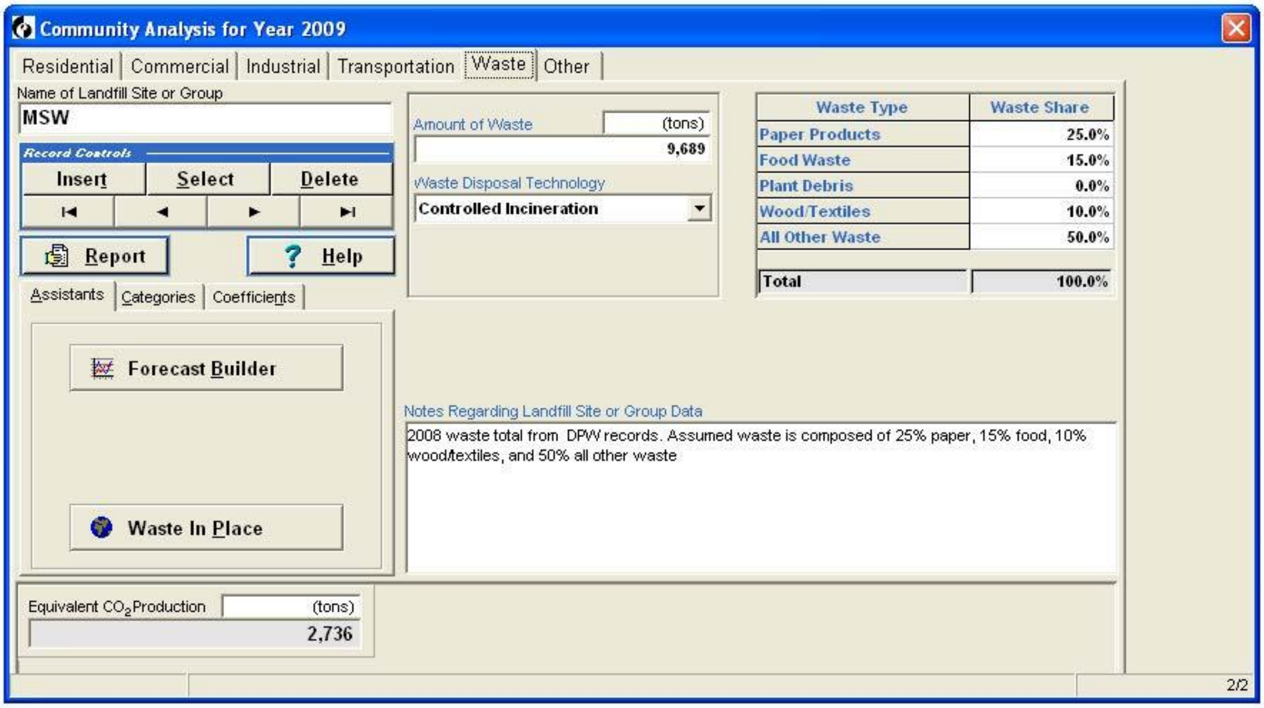
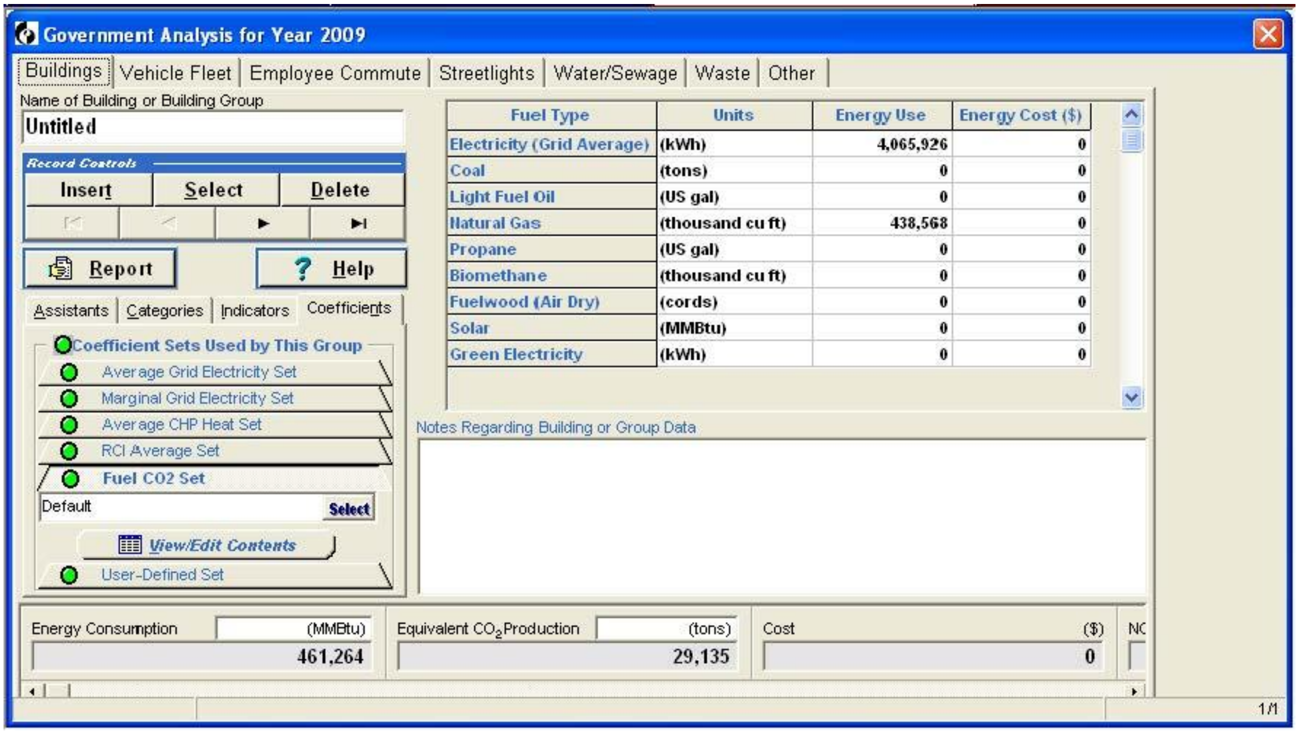


Table F7
Community GHG Results

	Equiv CO_2 (tons)	Equiv CO_2 (%)	Energy (MMBtu)
Residential			
Electricity	29,518	9.2%	274,165
Light Fuel Oil	23,184	7.2%	280,453
Natural Gas	31,878	9.9%	515,976
Subtotal	84,580	26.3%	1,070,595
Commercial			
Electricity	35,125	10.9%	326,250
Light Fuel Oil	3,715	1.2%	44,943
Natural Gas	29,609	9.2%	479,243
Subtotal	68,449	21.3%	850,436
Industrial			
Electricity	5,420	1.7%	50,346
Subtotal	5,420	1.7%	50,346
Transportation			
Gasoline	95,556	29.7%	1,119,785
Diesel	65,446	20.3%	754,549
Subtotal	161,002	50.1%	1,874,334
Waste			
Compost	(549)	-0.2%	
Paper Products	195	0.1%	
Food Waste	117	0.0%	
Wood/Textiles	78	0.0%	
All Other Waste	2,345	0.7%	
Subtotal	2,186	0.7%	
Total	321,637	100.0%	3,845,712

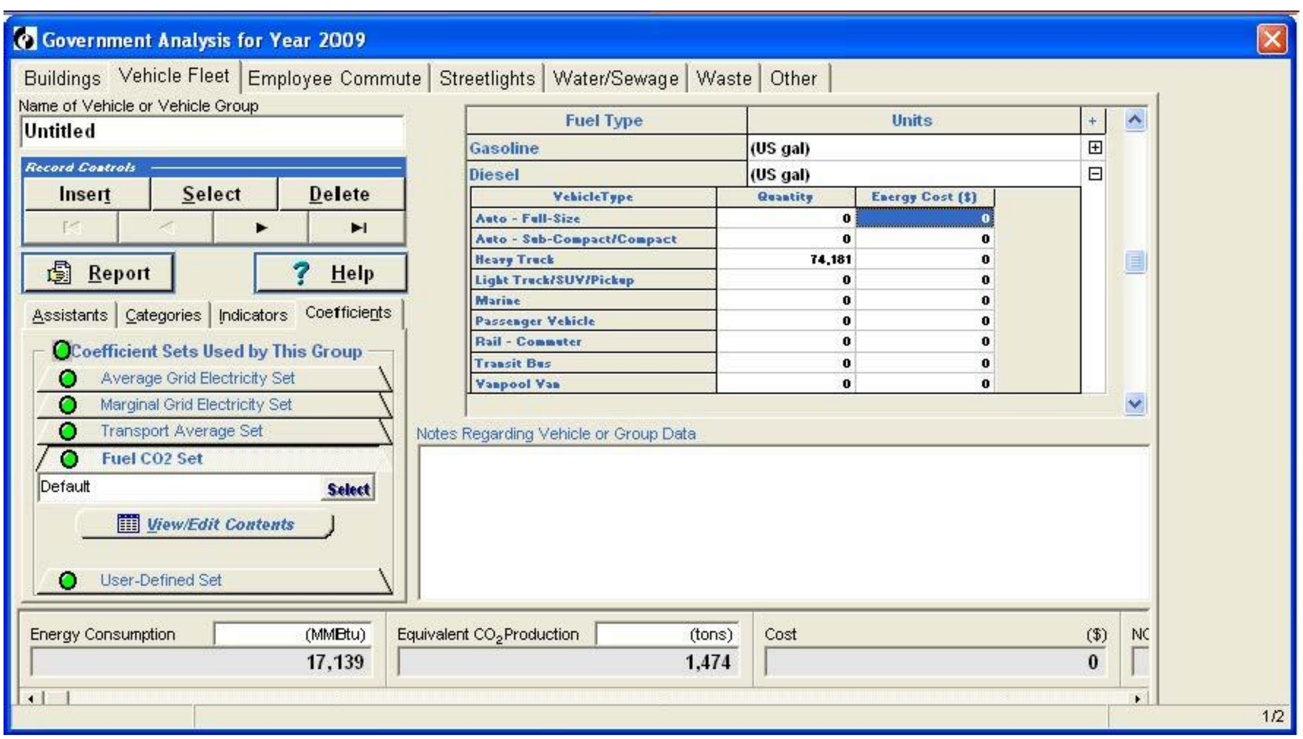
Table F8
Municipal Buildings Inputs



Fuel Type	Units	Energy Use	Energy Cost ($)
Electricity (Grid Average)	(kWh)	4,065,926	0
Coal	(tons)	0	0
Light Fuel Oil	(US gal)	0	0
Natural Gas	(thousand cu ft)	438,568	0
Propane	(US gal)	0	0
Biomethane	(thousand cu ft)	0	0
Fuelwood (Air Dry)	(cords)	0	0
Solar	(MMBtu)	0	0
Green Electricity	(kWh)	0	0

Energy Consumption (MMBtu)	Equivalent CO_2 Production (tons)	Cost ($)
461,264	29,135	0

Table F9
Municipal Vehicle Fleet Inputs - Diesel



Fuel Type	Units
Gasoline	(US gal)
Diesel	(US gal)

VehicleType	Quantity	Energy Cost ($)
Auto - Full-Size	0	0
Auto - Sub-Compact/Compact	0	0
Heavy Truck	74,181	0
Light Truck/SUV/Pickup	0	0
Marine	0	0
Passenger Vehicle	0	0
Rail - Commuter	0	0
Transit Bus	0	0
Vanpool Van	0	0

Energy Consumption (MMBtu)	Equivalent CO_2 Production (tons)	Cost ($)
17,139	1,474	0

Table F10

Municipal Vehicle Fleet Inputs - Gasoline

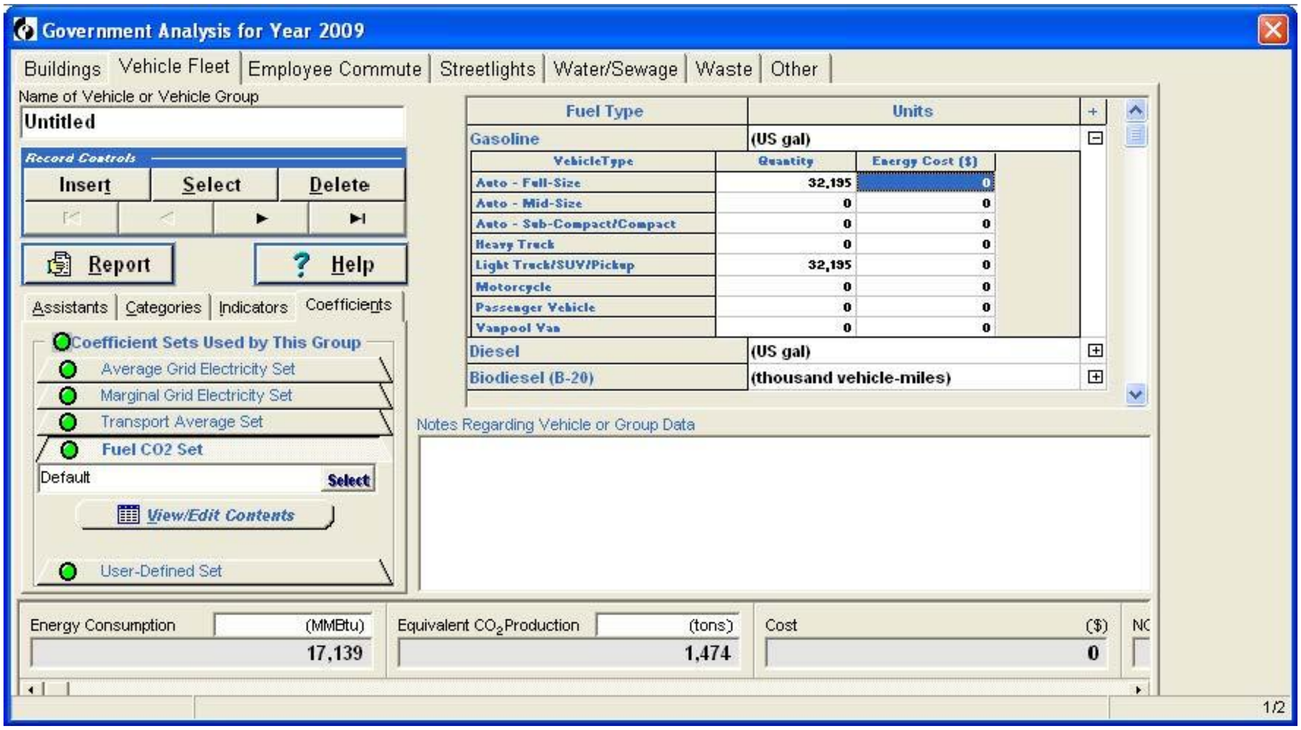


Table F11

Municipal Streetlights Inputs

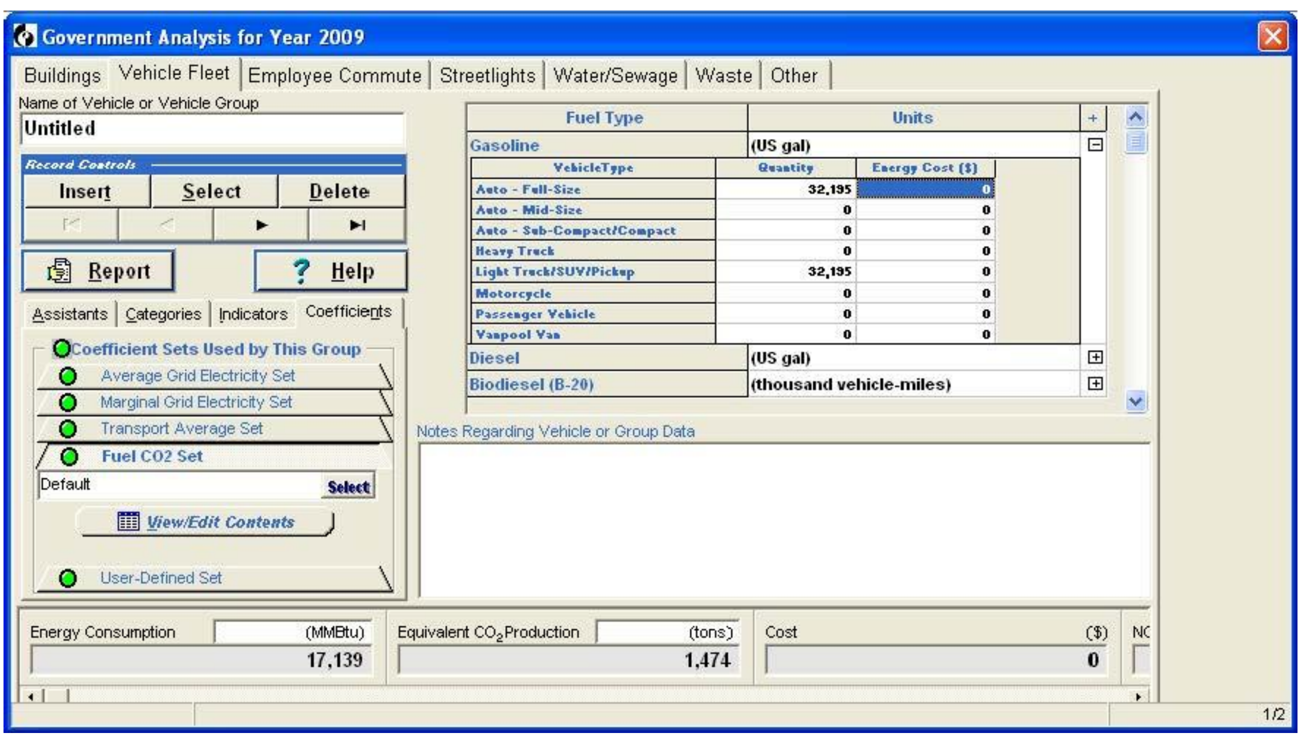


Table F12
Municipal Water/Sewage Inputs

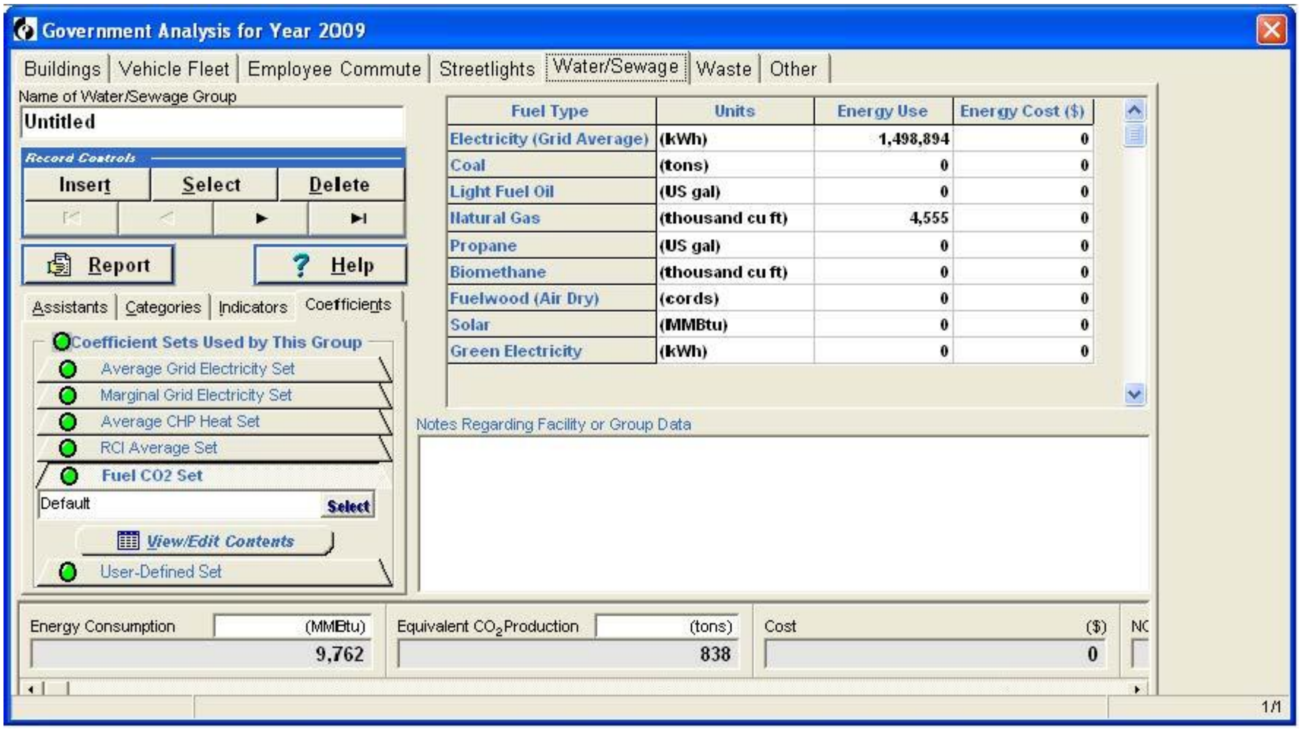


Table F13
Municipal Waste Inputs

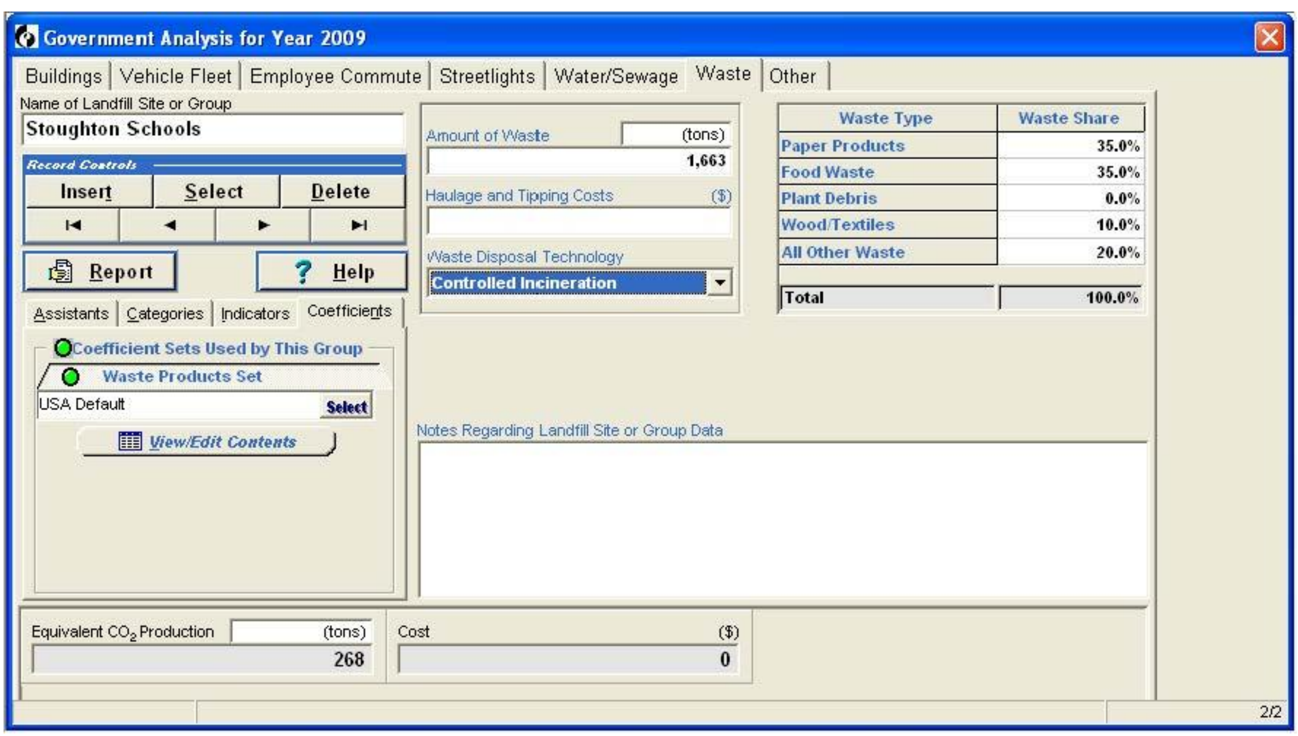


Table F14
Municipal GHG Results

	Equiv CO_2 (tons)	Equiv CO_2 (%)	Energy (MMBtu)
Buildings			
Electricity	1,494	19.9%	13,878
Natural Gas	2,996	39.8%	48,496
Subtotal	4,490	59.7%	62,374
Vehicle Fleet			
Electricity	1,474	19.6%	17,139
Subtotal	1,474	19.6%	17,139
Streetlights			
Electricity	451	6.0%	4,188
Subtotal	451	6.0%	4,188
Water/Sewage			
Electricity	836	11.1%	9,733
Natural Gas	2	0.0%	29
Subtotal	838	11.1%	9,762
School Waste			
Paper Products	94	1.2%	
Food Waste	94	1.2%	
Wood/Textiles	27	0.4%	
All Other Waste	54	0.7%	
Subtotal	268	3.6%	
Total	7,521	100.0%	93,463