Marshfield Energy Use and Greenhouse Gas Emissions Inventory- 2008

Marshfield, Massachusetts

NSTAR Electric 2009

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Acknowledgements

Many people were involved in the creation of this carbon inventory but I would particularly like to thank: Megan Amsler of Cape and Islands Self-Reliance; Derek Buchler of Bay State Gas; David Carriere, Superintendent of the Marshfield Department of Public Works; Dr. George Cicchetti of the Marshfield Energy Committee; Susan Flynn of the Marshfield Accounting Department; Paul Halkiotis, Marshfield Town Planner; Susan Haselhorst of NSTAR Electric; Gia Lane of the Marshfield Energy Committee and Martha Totman of Totman Enterprises.

1. Executive Summary (Return to Table of Contents)

1.1 Introduction

The effects of the global warming from the greenhouse effect are of growing concern to both national and local governments. Many communities are now working to mitigate their effect on climate change by taking steps to reduce their emissions of greenhouse gases like carbon dioxide, methane and nitrous oxide which are released by the burning of fossil fuels for energy. Marshfield, Massachusetts is one such community and this inventory should provide a basis for climate change mitigation plans to come.

A carbon inventory is a study of energy consumption in a region and the emissions that result from the production of that energy and other sources. This inventory includes data for solid waste generation and electricity, heating fuel and transportation fuel use gathered from various governmental and utilities sources. It is split into two parts: a community inventory which includes emissions from the entire town and a municipal inventory which includes emissions from town buildings, vehicles and services.

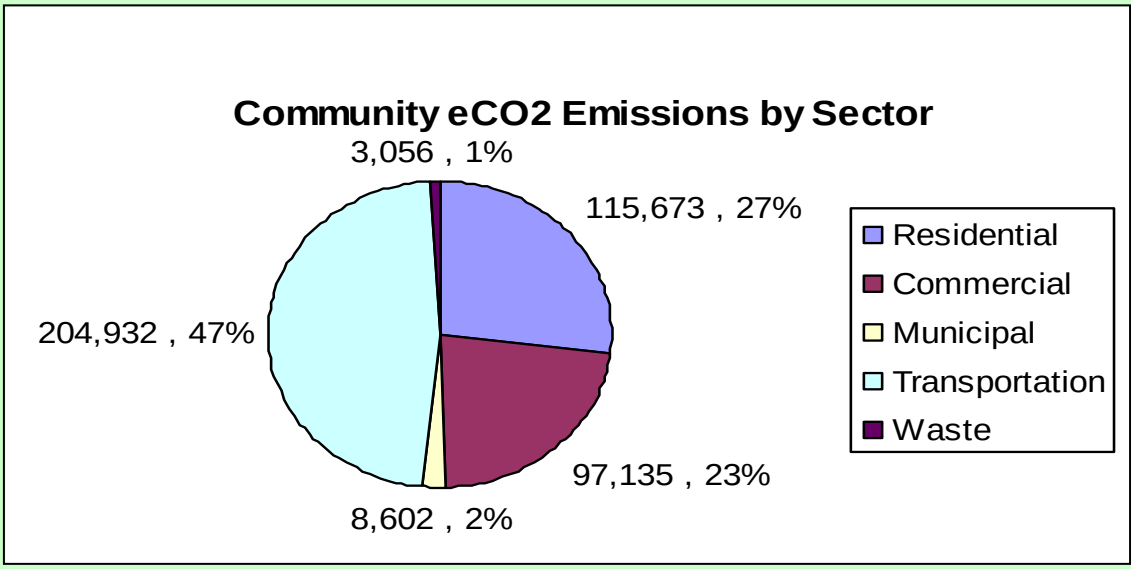
1.2 Methods

Most of the data used in this survey was gathered directly from energy billing data; those data that were not directly available were estimated from typical values and town census data. In the municipal portion of the inventory, electricity and natural gas data for the town buildings were collected from the utility providers NSTAR Electric and Bay State Gas, respectively, and cross-checked with town utility bills. Data on the town fleet and solid waste production was gathered from the Marshfield Department of Public Works. Energy costs were gathered from billing information and estimated from 2008 averages where necessary.

For the community portion of the inventory, NSTAR Electric and Bay State Gas provided total consumption in the residential and commercial sectors and other heating fuel data was estimated from national residential and commercial energy surveys. Emissions from community transportation were estimated from the length of roads in Marshfield and traffic counts conducted in the town by the Massachusetts Highway Department.

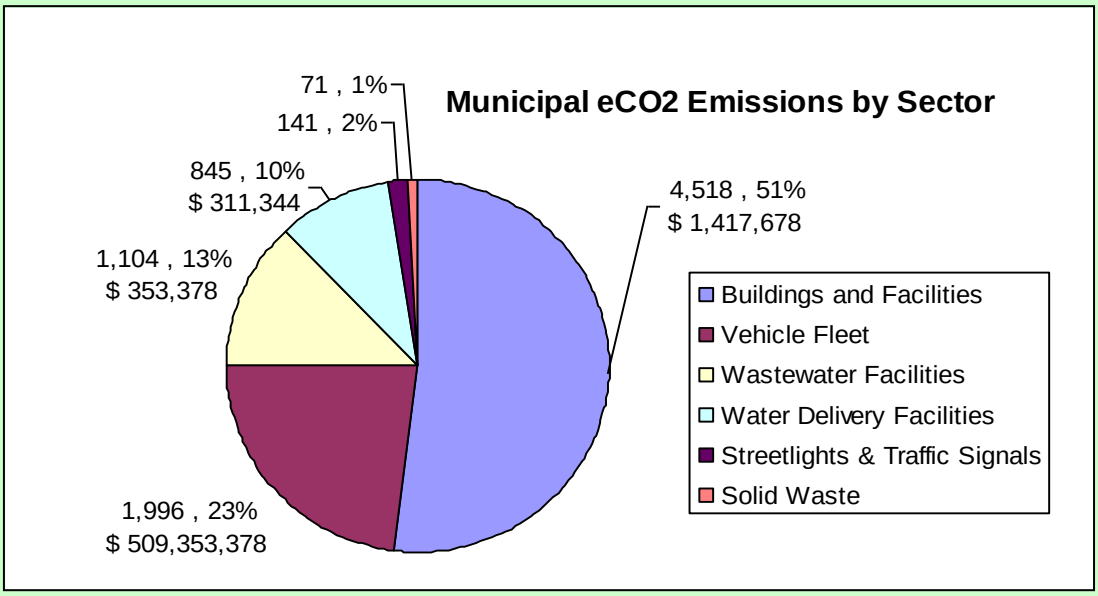
This data was then entered into the Clean Air and Climate Protection software provided by ICLEI – Local Governments for Sustainability to its member governments. The software includes a calculator which uses pre-set coefficients to estimate greenhouse gas emissions from such data and includes a module to project future emissions growth.

1.3 Results



This inventory found that Marshfield emitted a total of about 429,399 metric tons (tonnes) of eCO2 in 2008, almost half of which was emitted by vehicles within the town. The rest was emitted by residential energy use, commercial energy use, municipal energy use and solid waste.

Of the 8,602 tonnes of greenhouse gases emitted by the Marshfield government, just over half, was emitted by the municipal buildings and facilities. The remainder was emitted by the vehicle fleet, water and wastewater facilities, town lighting and solid waste. The energy costs of these sectors reflect the energy use with the buildings and facilities having the highest energy costs and the other sectors following.



1.4 Next Steps

The Energy Committee in Marshfield, comprised of citizens and town officials, is currently working on plans to increase the town's efficiency, save money and, ultimately, reduce greenhouse gas emissions in every sector. The town of Marshfield has applied for a "Green Community" designation with the MA Department of Energy Resources which brings with it resources for reducing energy consumption and cutting emissions. One criterion for becoming a Green Community is to an annual reduction of energy consumption of **4%** over a five year period for a cumulative reduction of **20%** for **municipal buildings**. This goal should be considered by the Energy Committee for recommendation to the Board of Selectmen. This is a goal and there is no penalty for not reaching the goal.

The result of the Marshfield Energy Challenge initiatives was a **2.5%** reduction in energy consumption for **residential** and **commercial buildings** over a one year period. A goal of a **2%** reduction in energy consumption and greenhouse gases emissions should be considered by the Energy Committee for recommendation to the Board of Selectmen.

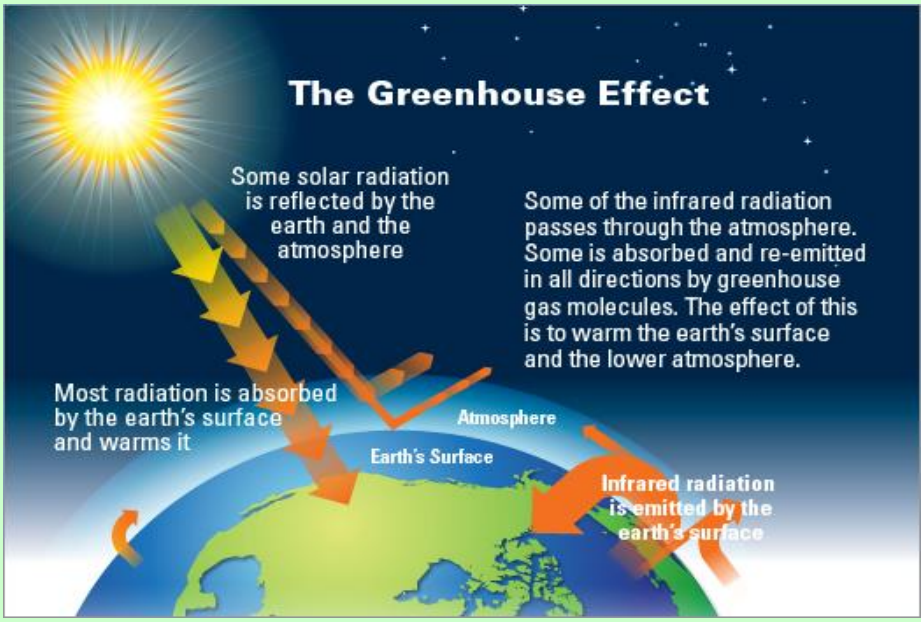
The committee has already discussed several options for both municipal and community emissions reductions and some are already in the works. These plans can be developed into a climate action plan. Some examples are helping to increase residential and commercial efficiency improvements by marketing free MassSave residential energy audits and commercial efficiency programs offered through NSTAR Electric and Bay State Gas and offering educational seminars to residents of the town.

The Marshfield Energy Committee is also in the process of exploring sites for installing a wind turbine in the town through the Massachusetts Renewable Energy Trust. Also, based on the results of this inventory, the town administrator has completed an Energy Services Contract RFQ which was approved by the Department of Energy Resources and the town is in the process of reviewing five Energy Services Companies (ESCOs) who have applied to perform audits and retrofitting on town buildings for guaranteed energy savings.

2. Introduction (Return to Table of Contents)

2.1 Global Climate Change

Figure 1: The Greenhouse Effect



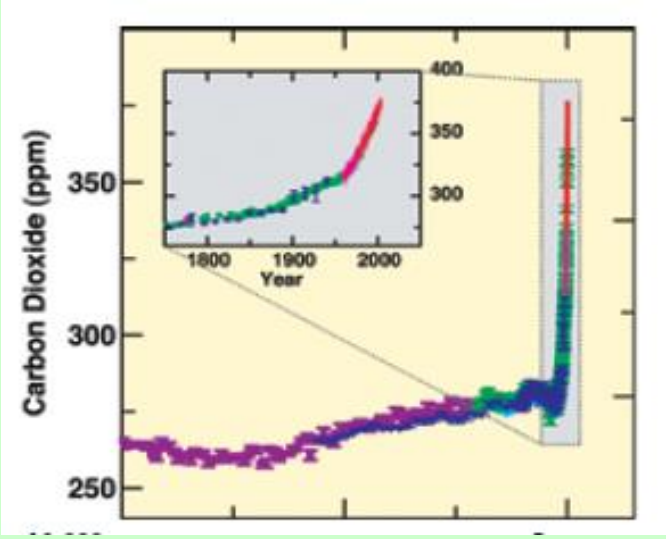
Global climate change is any long-term change in the world's climates, including changes in temperature, precipitation or wind patterns. Climate change may be due to a number of natural factors, but recently scientists have detected a man-made source of climate change: global warming due to greenhouse gases (GHGs) released through the burning of fossil fuels and other processes. These processes release compounds which help contribute to the atmosphere's "greenhouse effect" by which the gases in the air trap radiation from the sun which is reflected off of the earth's surface (Fig 1). This effect helps heat the earth to habitable temperatures but increasing levels of these gases mean the overall temperature of the planet rises as well. This global warming has consequences beyond slightly warmer ambient temperatures; even small temperature changes have the potential to disrupt climate patterns and cause flooding, drought, heat waves, powerful hurricanes, blizzards and other extreme weather events. These events can also have cascading effects on wildlife diversity, agriculture, water resources and human health[1].

In the past century, the annual global temperature has risen by about 1.3 ºF and it has been rising faster in more recent years. In the past 30 years, the

[1] http://www.epa.gov/climatechange/downloads/Climate_Basics.pdf

rate of heating increased to three times the rate of the last 100 years. In the northeastern United States, the annual average temperature went up 2 ºF in the past 30 years while winter temperatures saw an increase of 4 ºF[2]. These temperature shifts have corresponded with large increases in atmospheric levels of GHGs such as carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) since the industrial revolution (Fig 2). Scientists studying this phenomenon in the Intergovernmental Panel on Climate Change (IPCC) agree that the rising levels of these gases are not only the cause of the global warming we are now experiencing, but also very likely come from human activities[3].

Figure 2: Atmospheric carbon dioxide" 10,000 years ago to present



Global climate change is expected to have a great impact on the northeastern region of the United States, particularly on coastal communities like Marshfield. A study by the United States Global Change Research (USGCR) program predicts many changes to the local climate including increasing extreme temperatures, declining air quality, more frequent flooding from rain and rising sea levels and diminished lobster fishing in some parts of the region. Already, rising temperatures in the region have resulted in:

- more frequent very hot days
- longer growing season
- increase in heavy downpours
- less winter precipitation falling as snow and more as rain, reduced snowpack
- earlier break-up of winter ice on lakes and rivers, earlier spring snowmelt resulting in earlier peak river flows

[2] http://www.globalchange.gov/
[3] http://www.epa.gov/climatechange/downloads/Climate_Basics.pdf

- rising sea surface temperatures, and rising sea level and rising sea levels will be of particular concern to Marshfield as it will result in coastal flooding, erosion, property damage and loss of the wetlands[4].

2.2 Marshfield, Massachusetts

Demographics

Marshfield is a town located on Massachusetts Bay with a population of about 24,500 people in 9,000 households[5]. Marshfield is heavily comprised of families; 74% of households are defined as "family" compared with 65% statewide. It also has a higher proportion of children under 14 and adults aged 35-60 than the rest of the state and a larger average household size. It is a relatively affluent town, with a median household income of $66,508 which is 32% higher than that of Massachusetts ($50,502) and relatively low unemployment and poverty rates, at 1.9% and 3.8%, respectively[6].

History

Incorporated in 1640, Marshfield has seen many changes over the years from when it was populated by the Wampanoag Native Americans before European settlements to modern times. Marshfield is a town tied to its coastline; early industries included fishing, salt marsh haying and shipbuilding, which sprouted various industries to supply the ships, saw mills, cotton mills, grist mills, tanneries, ship chandleries as well as fulling mills, iron furnaces, factory boarding houses and company stores. Farming was another early industry in the town, although most of the farmland has now been developed into housing. Marshfield's Green Harbor is still in heavy use by commercial lobstermen and tuna fishermen as well as pleasure boaters[7].

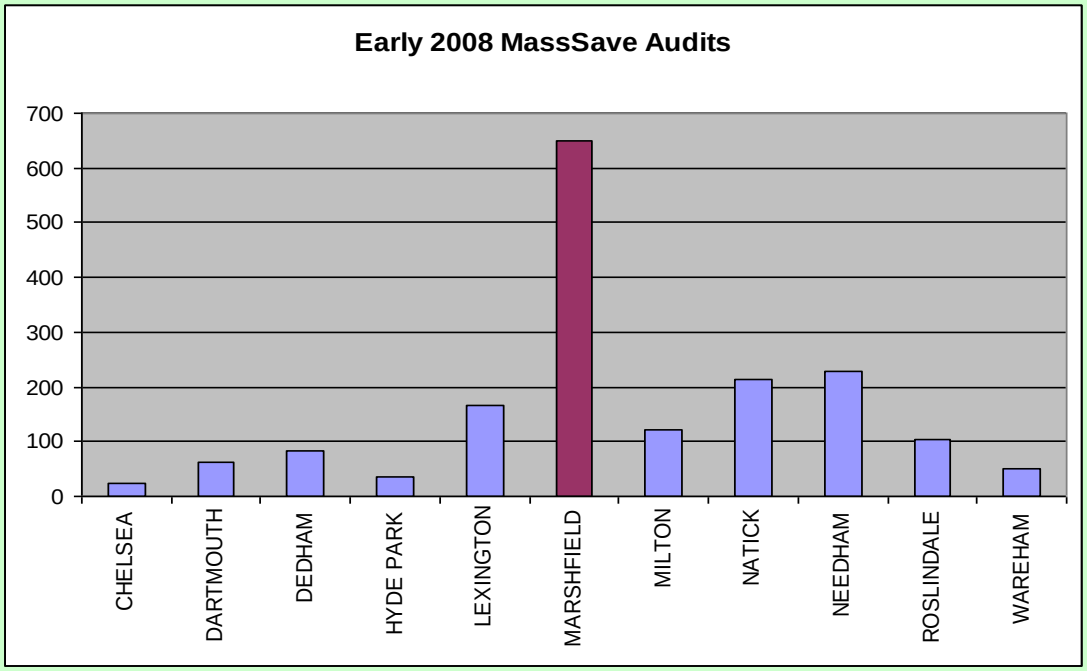
2.3 Green Community Movement

Marshfield is now working to become a "green" community and doing its part to reduce its carbon emissions and impact on the environment. The citizens and government of the town realize there is much at stake – both for their own stretch of coastal land and the environment in general. In 2008, the town agreed to participate in a yearlong pilot program offered by NSTAR

[4] http://www.globalchange.gov/
[5] http://factfinder.census.gov/
[6] Marshfield Pilot Design Report sponsored by NSTAR Electric & Gas Corporation and the Massachusetts Technology Collaborative and prepared by Rocky Mountain Institute, Energy & Environmental Economics, Inc. and Freeman, Sullivan & Co.
[7] http://www.marshfieldchamberofcommerce.com/history.php

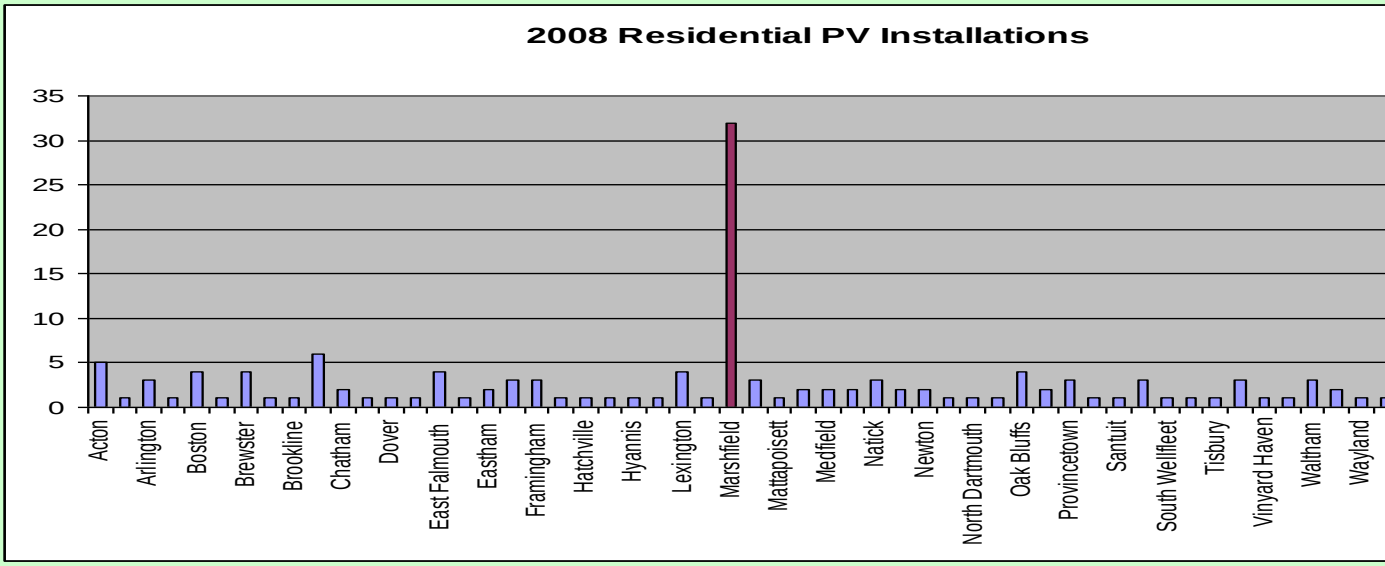
Electric called the *Marshfield Energy Challenge* which encouraged citizens to participate in energy-reducing measures and solar panel installation projects.

Figure 3: MassSave audits conducted January-April 2008, selected towns



The energy challenge had several significant accomplishments in achieving GHG emissions reductions. Over 1,200 homes – compared to only about 50 in 2007 – and 100 businesses conducted energy audits and implemented efficiency measures (fig. 3 shows preliminary residential results as of April 2008). Over 30 homes installed photovoltaic solar panels (PV) – a record in Massachusetts (fig. 4) – while three PV systems are to be installed on town facilities and two on commercial facilities. Additionally, Marshfield has installed high efficiency lighting in seven town facilities and had over 500 students participate in programs teaching about energy efficiency. Overall, NSTAR estimates a total residential savings of more than **2.5%.**

Figure 3: Residential photovoltaic systems installed in NSTAR territory, 2008



In 2008, the Board of Selectmen authorized the formation of an internal energy committee comprised of town officials and concerned citizens and funded with the help of a grant from NSTAR. Marshfield has applied for designation as a Green Community through the Massachusetts Green Community Act, signed into law July 2008. This designation will bring with it funding and resources from the state to assist in energy conservation and renewable energy generation.[8]

The town also joined the organization ICLEI-Local Governments for Sustainability which is a resource for communities wishing to reduce the pollution including GHG they emit. ICLEI provides support and tools such as the Clean Air and Climate Protection (CACP) software used to calculate emissions in this inventory as well as guidelines and protocols to help communities set and reach emissions reductions goals. This carbon inventory is the first step in ICLEI's "Five Milestones for Climate Mitigation":

- Conduct a baseline emissions inventory and forecast
- Adopt and emissions reduction target for the forecast year
- Develop a Local Climate Action Plan
- Implement policies and measures
- Monitor and verify results[9]

Based on the Marshfield Energy Challenge's successes, the energy committee has begun to form savings plans and goals for the next few years. They hope to continue the efforts of the challenge to achieve **2%** savings in 2009-2010 (for more details, see sections 6-7 of this report).

[8]http://www.mass.gov/?pageID=gov3pressrelease&L=1&L0=Home&sid=Agov3&b=pressrelease&f=080702_bill_energy_clean&csid=Agov3

[9] http://www.icleiusa.org/

3 Methods (Return to Table of Contents)

3.1 Emissions Inventory Introduction

A carbon inventory is a study of energy consumption in a community or region and the emissions that result from the production of that energy. It can be taken as a first step in a movement to reduce GHG emissions and clean up the community by identifying the largest users and helping to set goals and priorities. This carbon inventory is composed of two parts that each focus on municipal or community sources of emissions in the calendar year 2008. The municipal study includes GHG emissions from electricity and heating fuels in all town buildings, the waste water pumps and treatment plant, potable water wells and distribution system, gasoline and diesel used by town vehicles, electricity consumed by street and traffic lights and solid waste generated by all town departments. The community portion of the study involves town-wide totals of GHG emissions from electricity, heating fuels, transportation fuels and solid waste generation and is broken down by sector into residential, commercial, transportation and waste sources.

An important element in conducting the inventory was the Clean Air and Climate Protection (CACP) software provided by ICLEI to its member governments. The CACP software includes a calculator which uses pre-set coefficients to estimate GHG emissions based on energy consumption and other data. The emissions are calculated in terms of equivalent carbon dioxide (eCO_2) which includes the effects of gases other than CO_2 which have different heat absorption properties and therefore different greenhouse effects in the atmosphere. The quantity of each gas is converted into the quantity of CO_2 which would have the same greenhouse effect so the emissions may be reported in a single value. This allows for simple emissions reports which can generate a single value stating the results of complex energy consumption data (Table 1).

Table 1: eCO_2 emissions by source[10]

Emissions Source	Unit	Equivalent BTU	eCO_2 (kg)	BTU / kg emissions
Electricity	kWh	3,412	0.415	8,222
Natural	Ther	100,000	5.32	18,797

[10] http://www.iso-ne.com/genrtion_resrcs/reports/emission/2007_mea_report.pdf

Gas	m			
Gasoline	Gallon	124,225	8.97	13,849
Diesel	Gallon	138,676	10.15	13,663

The CACP software takes inputs for community and municipal emissions sources broken down into sector and facility and can generate reports of total emissions by sector, location or individual location inputs. The data from these reports was exported into excel to be analyzed and graphed for this inventory. Although the CACP reports do include emissions by each GHG, this inventory used only the eCO_2 reported in metric tons (tonnes) for simplicity.

3.2 Data Sources

The largest portion of work behind this inventory was dedicated to gathering data on energy consumption by the various buildings and sectors in town. Some of the data in this report was estimated from average uses and census data, but most is actual consumption gathered from various sources through the cooperation of several town departments and utility companies. Community transportation and non-natural gas heating data was gathered from various governmental sources and utility providers and will be noted where referenced (Table 2). (See Appendix D for the complete dataset.)

Table 2: Data Sources and Source Year

Sector	Emissions Source	Data Source
Municipal Buildings	Electricity	Town Hall accounting off NSTAR Electric billing da
Municipal Buildings	Natural Gas	Town Hall accounting off Bay State Gas billing da
Municipal Water Treatment/Pumps	Electricity	Department of Public Wo NSTAR Electric billing da
Municipal Water Pumps	Propane	Department of Public Wo
Municipal Fleet	Transportation Fuel	Department of Public Wo Totman Enterprises
Municipal Solid Waste	Solid Waste	Department of Public Wo Transfer Station

Community	Electricity	NSTAR Electric
Community	Natural Gas	Bay State Gas
Community	Transportation Fuel (estimated)	Department of Public Wo
Community: Residential	Other Fuels (estimated)	Residential Energy Consumption Survey (RE
Community: Commercial	Other Fuels (estimated)	Commercial Buildings En Consumption Survey (CBE
Community	Solid Waste	Department of Public Wo Massachusetts DEP

3.3 Community Emissions Inventory Methods

The community emissions inventory included four sectors: residential, commercial, solid waste and transportation. The emissions sources for the residential and commercial sectors included electricity, natural gas, fuel oil, liquid petroleum gas (LPG) and wood consumption. All electricity and gas data was provided by NSTAR electric and Bay State Gas, respectively. Each company drew data on all usage in Marshfield from 2008 and summed by sector (commercial or residential) to give a total in kWh or Therms to input directly into the CACP software. These totals included all municipal electric and gas use in the commercial sector.

The use of other fuels was estimated using averages since they may be purchased from multiple providers unlike electricity and natural gas. The US Energy Information Administration (EIA) conducts and publishes surveys every several years of residences and commercial buildings (RECS, 2005 and CBECS, 2003) that include the number and average use of households or businesses for various fuels. For the residential sector, the number of households in Marshfield using a particular fuel type (LPG, fuel oil and wood) was estimated by multiplying the number of households in Marshfield by the percent of households in New England that use that fuel type. Vacant homes were estimated to use 50% less fuel than the average use[11]. The total use of each fuel was calculated from multiplying this adjusted number of households by the average fuel consumption reported in RECS[12].

For the commercial sector, the number of businesses using fuel oil as heat was estimated by subtracting the number of businesses heated with natural gas from BAY STATE GAS from the number of businesses which purchase

[11] The number of vacant homes was not completely eliminated from this estimate because of the large number of households reported as "vacant" in the 2005 census which may have been inaccurately reported. It is likely that some of these houses are actually seasonal rentals or households that did not respond to the survey.

[12] http://www.eia.doe.gov/emeu/recs/

electricity from NSTAR[13]. This number was multiplied with the average fuel oil consumption by commercial buildings in New England from CBECS[14].

The transportation emissions in the town were estimated from traffic counts and the length of roads in Marshfield provided by the DPW. The CACP software calculates vehicle emissions based on vehicle miles traveled (VMT) which is a product of road length and annual average daily traffic counts (AADT). The AADT was estimated from Massachusetts Highway Department statistics gathered in Marshfield[15]. Two recent annual traffic counts were available for Marshfield; both were located near the busy downtown. A factor of 15 % was included to account for the high-use count locations.

The quantity of solid waste generated from the town was a sum of the waste collected by the municipality and by private haulers. The solid waste transfer station which handles all of the waste collected by the town provided the total tonnage collected in fiscal year 2009. The quantity of solid waste handled by private haulers was taken from an estimate by the Massachusetts Department of Environmental Protection (DEP) made for 2007[16]. Since the bulk of the waste was collected by the municipality and is transferred to a capped and lined landfill, the type of disposal selected in the CACP software was "managed landfill" for the total waste. The percentage of each type of waste was gathered from a 2007 EPA report which included quantities of discarded waste by type.[17]

The growth figure to project the 2008 data into 2011 was provided by NSTAR as 1%, which is the approximate growth of electricity and gas demand in New England. This was entered into the CACP software's forecasting module to calculate the expected increases in eCO_2 emissions by 2011.

3.4 Municipal Emissions Inventory Methods

The municipal emissions inventory included five sectors: buildings and facilities, vehicle fleet, waste and potable water treatment and pumping facilities, streetlights and traffic signals and solid waste. This section also includes the total energy costs for each sector, excluding solid waste. The buildings and facilities data was collected with the help of the energy committee which was able to gather a list of town buildings to be included in the inventory. The town accounting department supplied electric and gas account numbers from old electric and gas bills which included yearly

[13] The number of electrical customers is assumed to be the same as the number of businesses as all use electricity.
[14] http://www.eia.doe.gov/emeu/cbecs/contents.html
[15] http://www.mhd.state.ma.us/default.asp?pgid=content/traffic01&sid=about
[16] http://www.mass.gov/dep/recycle/priorities/dswmpu01.htm#recycling
[17] http://www.epa.gov/osw/nonhaz/municipal/pubs/msw07-rpt.pdf

consumption for many town buildings. For buildings whose bills were not available, NSTAR and BAY STATE GAS provided monthly billing data for the accounts provided which was summed for a yearly total.

For the other sectors, the Department of Public Works (DPW) provided records of electricity and propane use by the town water systems, transfer station and town garage, gasoline and diesel consumption by the town fleet and solid waste generated by the municipality. The town contracts out school busing and snow removal to the company Totman Enterprises who provided the quantities and cost[18] of diesel consumed by their equipment in work for the town.

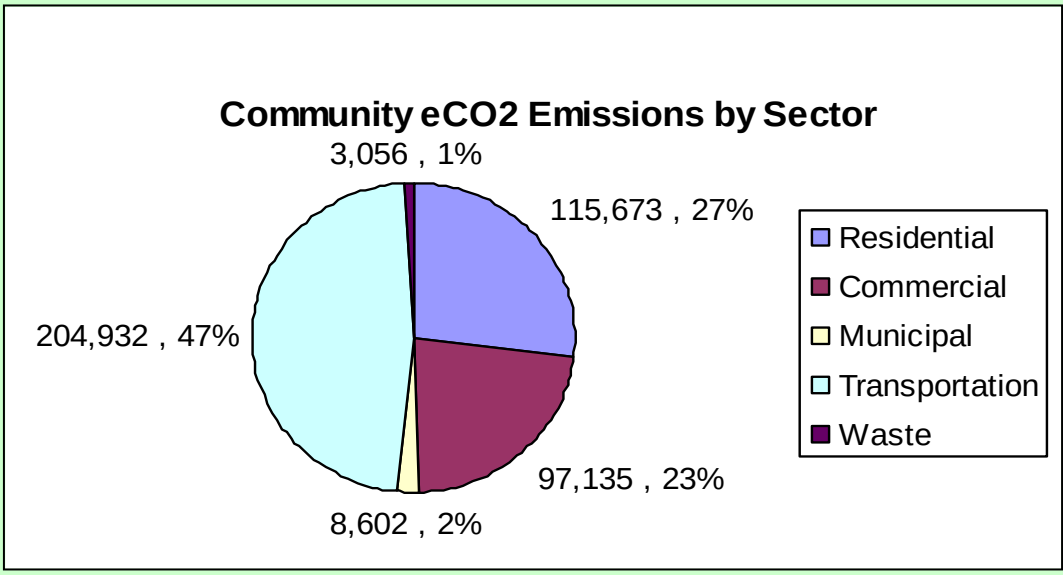
The electricity consumed by town lighting was collected from NSTAR and includes the town's street lighting account and miscellaneous accounts listed as lights belonging to Marshfield. It should be noted that there were several municipal electric accounts in Marshfield which were not identifiable as specific buildings or lighting and were not included in this portion of the inventory, although were part of the commercial sector in the community emissions findings.

[18] Cost provided was fuel costs paid directly by Totman Enterprises as fuel is part of the busing contract and not a direct expense of the town.

4 Findings (Return to Table of Contents)

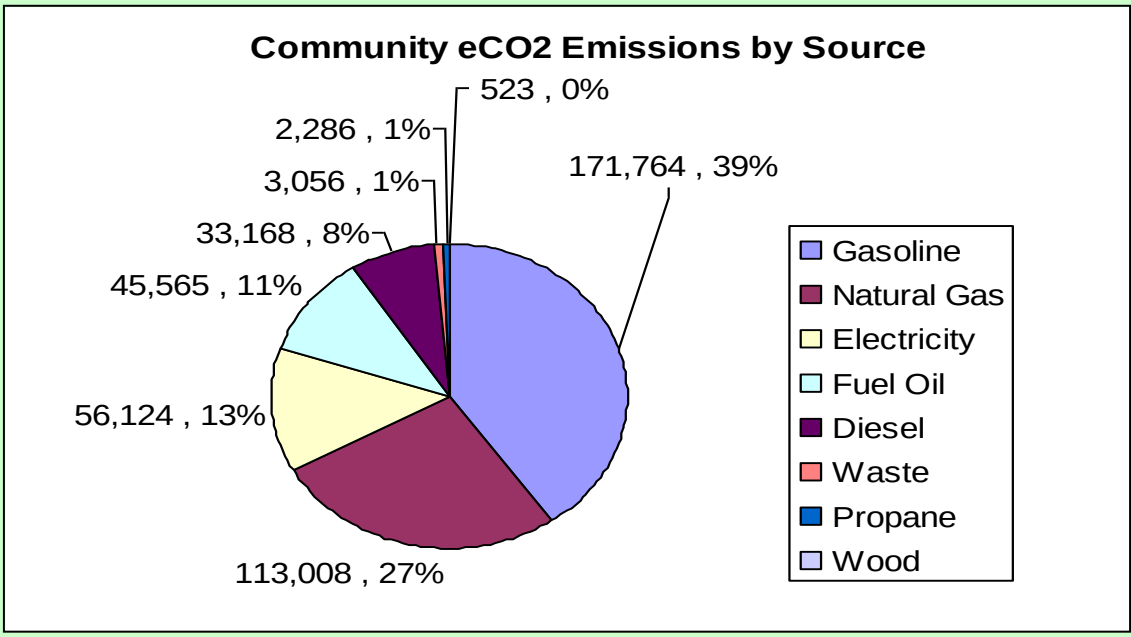
4.1 Community Emissions Findings

Figure 5: Community emissions by sector (tonnes)



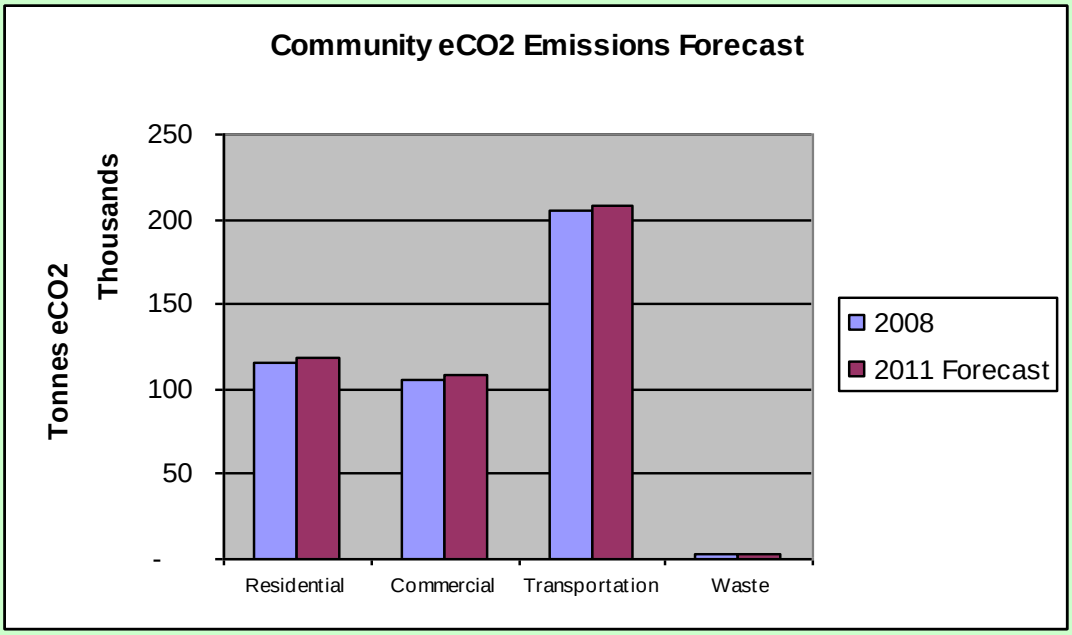
The Marshfield community emitted an estimated total of 429,399 metric tons (tonnes) of eCO_2 in 2008. The sector with the most emissions was the transportation sector with 204,932 tonnes eCO_2, with residential then commercial sectors following behind with 115,673 tonnes and 105,738 tonnes, respectively. The emissions from solid waste, 3,056 tonnes, accounted for only 1% of the total emissions (Fig. 5).

Figure 6: Community emissions by sector (tonnes)



Utility projections predict that energy consumption will grow about 1% annually which would result in a cumulative increase of about 2% in eCO_2 emissions by the year 2011 unless measures are taken to prevent this from happening. This increase would result in a total eCO_2 emission of about 439,215 tonnes in Marshfield in 2011 (Fig. 7).

Figure 7: Community emissions projections based on 1% growth rate



4.2 Municipal Emissions Findings

The Marshfield town government emitted about 8,602 tonnes of eCO_2 in 2008. More than half of these emissions, 4,518 tonnes, were generated by the buildings sector while the vehicle fleet and water facilities accounted for most of the rest with 1,996 and 1,948 tonnes, respectively (Fig. 8). The energy costs of these sectors reflect the energy use where the buildings sector has the highest costs and the other sectors following.

Figure 8:

Municipal emissions by sectors (tonnes)

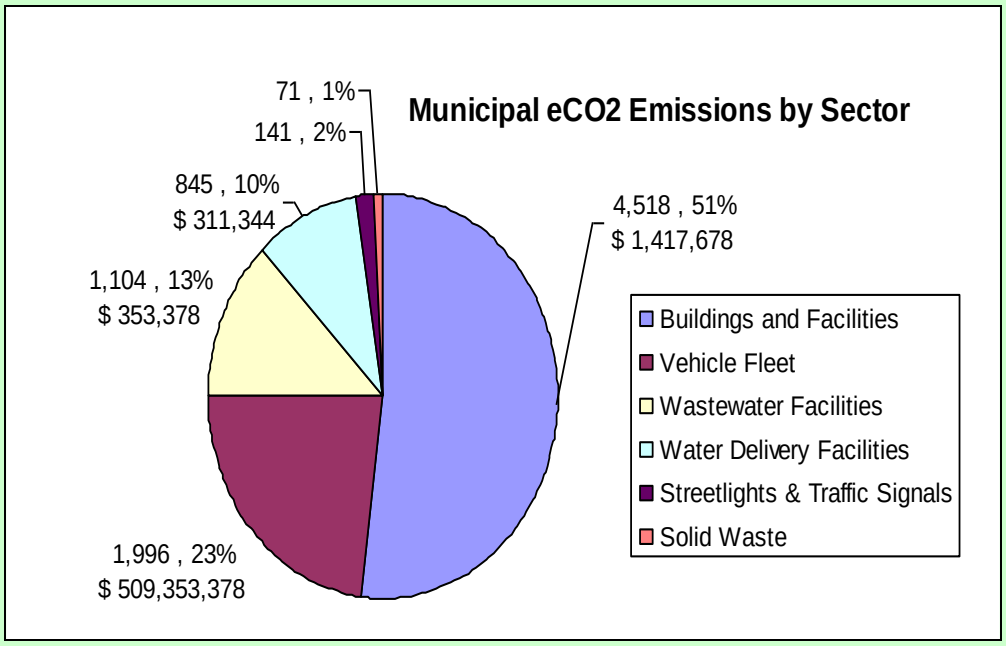
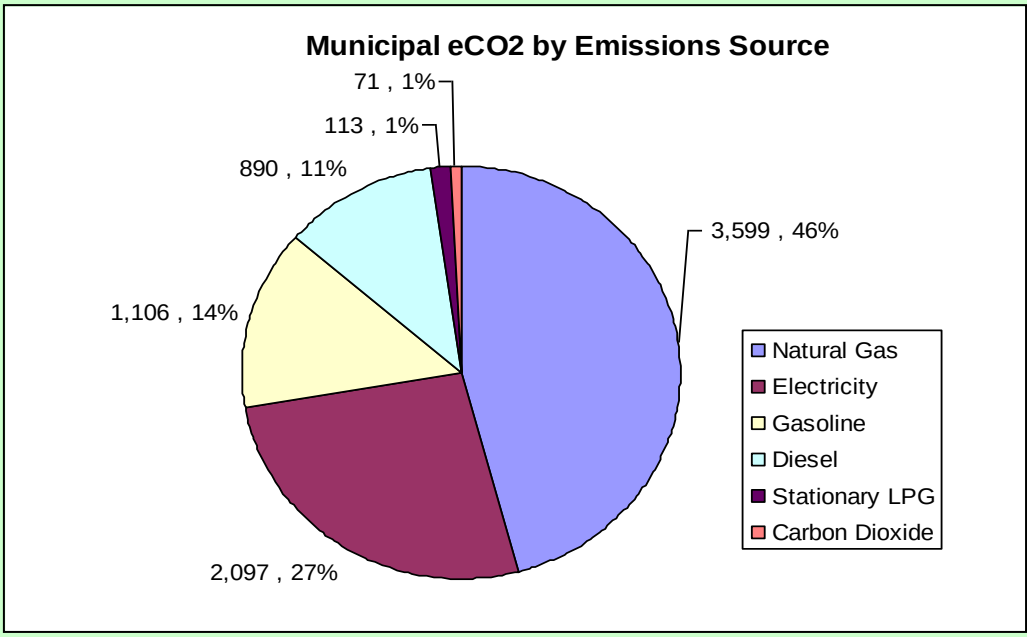


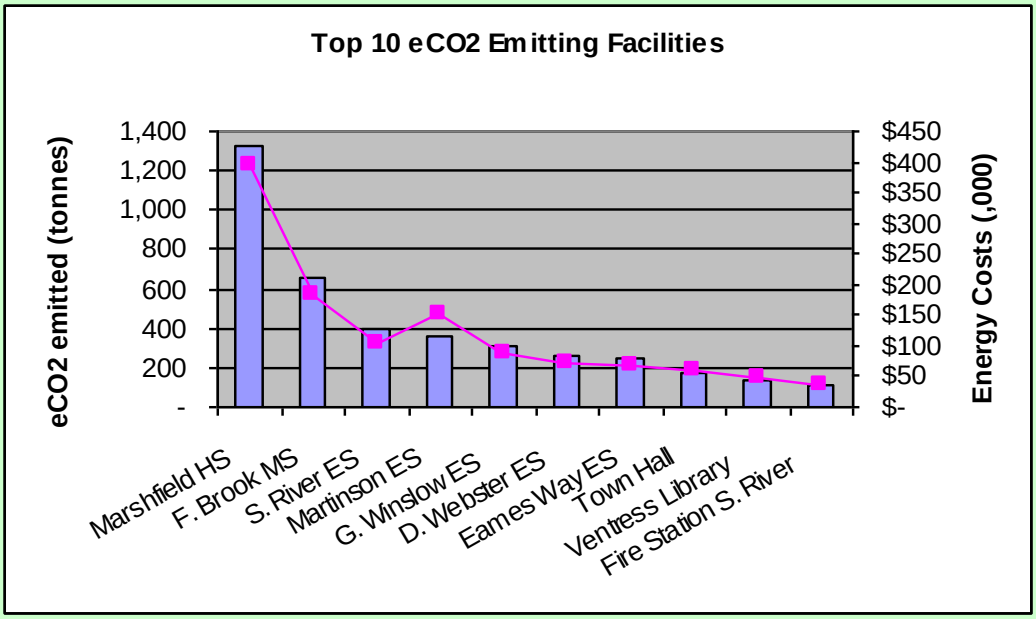
Figure 9:

Municipal emissions by source (tonnes)



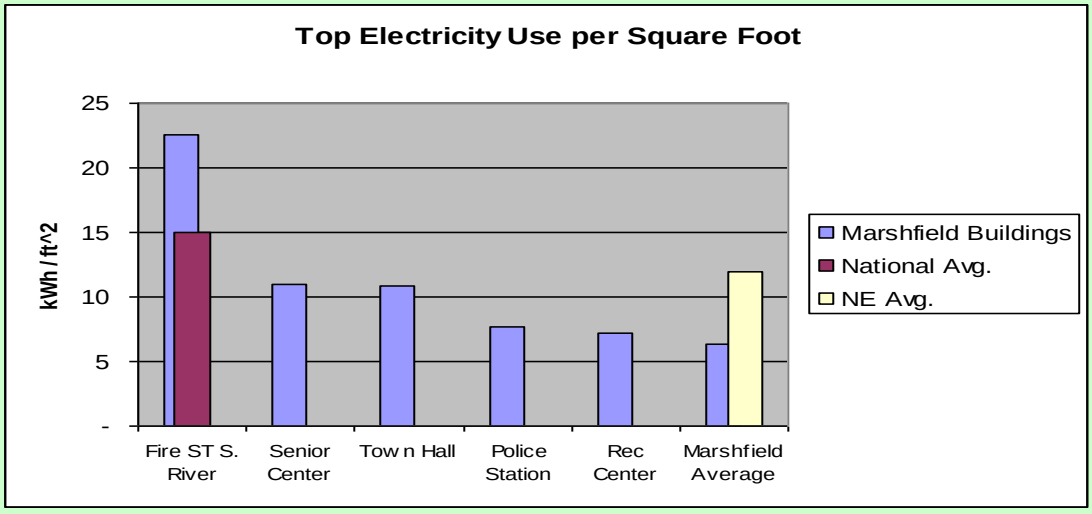
Marshfield High School was the single largest emitter of GHG in this sector with 1,326 tonnes of CO2 accounting for 15% of the town's emissions. The seven schools were also the top seven emitters overall, followed by the town hall, library, fire station on South River St. and the senior center (Fig. 10).

Figure 4: Top emitting municipal buildings with energy costs



The building with by far the most electricity use per square footage was the Fire Station on S. River Street. The fire station used 22.6 kWh/ft^2 in 2008, almost four times the average use of municipal buildings at 6.35 kWh/ft^2, although it is only about 42% higher than the national average electricity intensity for a "Public Order and Safety" building which is 15.3 kWh/ft^2 [19]. The next top electricity-using buildings were the Senior Center, Town Hall, police station and recreation center (Fig. 11). Of these buildings, the Senior Center, built in 2003, is the newest and should be examined most closely for the reason behind this high usage. It is interesting to note that, with the exception of the fire station, all of the municipal buildings in Marshfield use less electricity by area than the national average for commercial buildings. Whether this is due to the types of buildings included in these averages or reflects on Marshfield's high energy efficiency cannot be determined from the available data at this point, though may be a topic of future investigation.

Figure 5: Most electricity-intensive municipal buildings compared to national public safety averages and New England averages

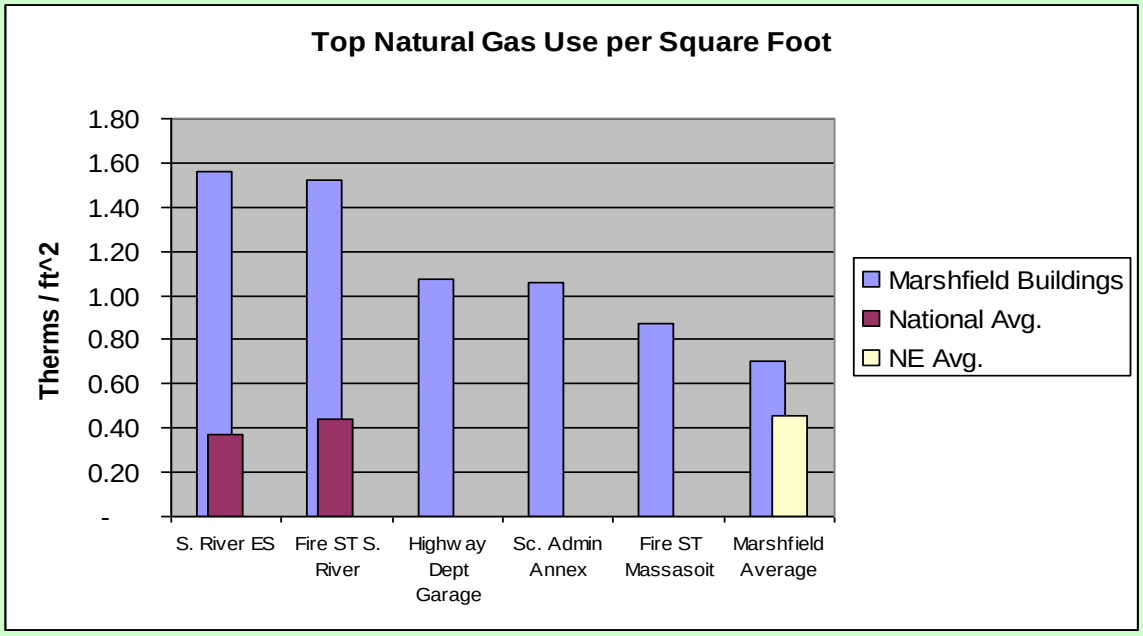


The building with the most natural gas use per square foot was the South River Elementary School which used 1.56 Therms/ft^2. This maximum was more than twice the average natural gas intensity of all the municipal buildings at 0.70 Therms/ft^2 and also more than twice the intensity of all of the school buildings in Marshfield which had an average of 0.72 Therms/ft^2 (Fig. 12). The national average natural gas intensity for educational buildings is 0.369 Therms/ft^2 which is well below Marshfield's

[19] http://www.eia.doe.gov/emeu/cbecs/contents.html
Please note that this average includes data from fire and police stations, jails and courthouses and may be higher or lower than the average energy intensity of fire stations alone

average natural gas intensity. Again, whether these discrepancies are due to the nature of the national averages available or waste on the part of Marshfield is left to be determined.

Figure 6: Most natural gas-intensive municipal buildings compared with national and New England averages



These nine buildings should be targeted especially for energy reductions as a high energy use per square foot can indicate waste and inefficiency. However, since the schools are the largest users overall, they have the highest absolute potential savings. The fire station on S. River should be a building of interest, as it is a high user of both natural gas and electricity and the only building that was in the top five users of each fuel by area. Other buildings of interest may also include Marshfield High School, which consumes almost twice the electricity as Furnace Brook Middle School with comparable square footage, and South River School, which consumes about twice as much natural gas as Eames Way Elementary School with comparable square footage. A comparison to more detailed regional benchmarks and comprehensive energy auditing will be necessary to determine if any of these energy intensities are unusual and should be targeted for improvements.

5 Next Steps (Return to Table of Contents)

This section was developed with the assistance of Dr. George Cicchetti of the Marshfield Energy Committee.

5.1 Potential GHG Reduction Goals

Residential and Commercial Goal - Some 1200 home energy audits, or about **13%** of Marshfield households, were conducted through the Marshfield Energy Challenge in 2008-09 and as a consequence homeowners installed compact fluorescent lights, programmable thermostats, insulation and air sealing and other energy efficiencies. NSTAR estimated that the energy efficiencies resulted in a reduction of about **2.5%** in energy consumption and GHG emissions.

Based on the Marshfield Energy Challenge results, the Energy Committee should consider setting and recommending to the Board of Selectmen an annual target of a **2%** reduction in residential and commercial energy consumption and GHGs for a five year period beginning 2009-2010. The cumulative effect of this goal would be a **10%** reduction within five years.

Municipal and School Buildings Goal - One of the criteria for achieving a designation as a Green Community and eligibility for funding is to establish an energy use baseline inventory for municipal buildings, vehicles, street and traffic lighting and put in place a comprehensive program designed to reduce this baseline by **20% within 5 years** of the initial participation in the program. The findings of this energy use and greenhouse gas inventory provide the baseline. The Energy Committee should consider setting and recommending to the Board of Selectmen an annual target of a 4**%** reduction in municipal consumption and GHGs for a five year period beginning 2009-2010. The cumulative effect of this goal would be a 20**%** reduction within five years.

This inventory identified the top electricity using municipal buildings by square footage and the top natural gas using buildings by square footage (figs 12 and 13). The energy committee has set a goal to reduce the energy consumption and costs and GHGs emissions for these buildings, however at this time predicting the causes for high consumption and emissions would be mostly speculation. The top-using buildings will be investigated more thoroughly and targets will be set for reduction of energy consumption when more is known.

5.2 Climate Action Plan Considerations

The energy committee is in the process of creating a climate action plan to help set and reach energy-saving targets. The plan is not yet complete but will take into account the results of this inventory, the Marshfield Energy

Challenge and Green Community requirements. The following sections contain potential plans and actions to be considered by the Energy Committee and recommended to the Board of Selectmen. Some of these plans have already been implemented.

- Encourage residential free home audits and commercial savings programs. (In progress)
- Hold educational seminars on energy and savings measures. (In progress)
- Setup and maintain a website (http://www.marshfieldenergy.org) to inform the community about energy saving plans and results. (In progress)
- Submit an application with the Massachusetts DEP for "Green Community" designation.
- Support obtaining a "Green Community" designation from the Massachusetts DOER. (In progress)
    - Application submitted August 7th 2009, awaiting approval
- Support an energy services contract to retrofit municipal facilities. (In progress)
    - Request for Quality application submitted to Massachusetts DOER August 14th 2009
- Perform a comprehensive energy audit of town buildings by DOER if an ESCO energy audit is not approved at Town Meeting
    - Have submitted application, audit expected to take place in late spring or early summer of 2010.
- Publicize and market free MassSave home energy audits. MassSave (www.masssave.com) is the primary in-the-home program offered by the gas and electric company jointly.
- Publicize and conduct Massachusetts Municipal Association home energy saving seminars from among the following: Introduction to Home Energy Savings, Weatherizing Your Home and Home Energy Savings for Retirees.
- Publicize and market a series of day and evening educational seminars with the focus on alternative energies and rebates.
- One possible action for reducing GHG emissions in Marshfield is the RFQ application which was approved August 14th by the Massachusetts DOER for an energy services contract. An energy services contract must be approved at a Marshfield town meeting. If the contract is approved, the Energy Services Company (ESCO) would perform investment grade energy audits and retrofits on Town-owned buildings. The costs of the work would be paid from the guaranteed energy savings resulting from the retrofits, and the ESCO would be responsible for maintenance. The town may also be able to take advantage of a Performance contract buy-down through competitive municipal grants offered by the Green Communities Act. If an ESCO is

approved at a town meeting, the action plans for municipal and school building and facilities would be developed and executed by the ESCO.

Note: NSTAR Electric and Bay State Gas are the program administrators for state mandated energy efficiency programs which offer information and incentives for implementation of energy efficient practices and equipment in buildings. Much detailed information is available on their respective websites[20].

Efficiency programs for residential and commercial customers are offered through existing gateways, specifically MassSave and NSTAR and Bay State Gas Commercial-Industrial programs. MassSave is a home audit and implementation service offered to any residential single-family dwelling that is a customer of either Bay State Gas or NSTAR Electric. The audit is a 1-2 hour in-the-home inspection by a trained auditor with services and products offered including a rebate for inefficient refrigerators, installation of high efficiency lighting, insulation and air-sealing measures of which the utility will pay 75%. The service includes a high-quality home assessment, no cost compact fluorescent lights (CFLs) and an assessment of other energy opportunities which are summarized below.

Commercial savings measures may be implemented through NSTAR or Bay State Gas Commercial-Industrial programs which offer a variety of services and incentives tailored specifically to business, institutional, and government establishments.

5.3 Renewable Generation

The Massachusetts Renewable Energy Trust (MRET) is mandated with promoting renewable energy and was a co-sponsor of the MEC. The MRET provides technical assistance and incentives for the implementation of the following:

Solar Photovoltaic (PV) – PV technology uses an easily-installed panel to capture the sun's energy and produce electricity. Solar arrays work to produce free, emission-free electricity as long as the sun is shining, though they unfortunately have a high initial cost compared to other fuel sources.

Wind turbine – Wind technology captures the kinetic energy of wind to power an electrical generator and create electricity. Wind is cheaper than PV technology and can be competitive with traditional fuel prices. Wind turbines can be installed locally by municipalities which can sometimes lead to

[20] http://nstar.com/residential/energy_efficiency/electric_programs/
http://www.baystategas.com/en/save-energy-money.aspx

concerns about local views, though many communities feel more positive about the turbines once they are installed.[21]

Combined heat and power (CHP) – CHP is a process where the waste heat resulting from electricity generation is used to water and space heating needs. This increases the efficiency of facilities with large heating needs such as hospitals, nursing homes and hotels.[22]

At this time, the Marshfield Energy Committee has submitted sites for a site survey for the possible installation of a municipal wind turbine to MRET. An engineer has conducted a walk through of site and preliminary analysis. The final report has not been issued.

[21] http://www.masstech.org/cleanenergy/technologies.htm
[22] http://www.epa.gov/chp/

6 Energy Savings Plans (Return to Table of Contents)

6.1 Energy Committee Plans

Based on the results of this carbon inventory, Marshfield's energy committee will develop a Carbon Reduction Plan to cut energy use and GHG emissions in the town. The energy committee will consider in their plan actions and recommendations that will be most effective at creating awareness and action in the community. This section identifies the relative impact of specific measures that members of the community may implement and some of the resources available to promote and subsidize the measures.

6.2 Tabulation of Relative Savings and Costs

Effectiveness is an important consideration in promoting energy-saving measures and renewable generation capabilities in a community. Measures that are easily implemented at low cost to the customer will show higher participation rates resulting in larger GHG emissions reductions. Table 4 contains a summary of measures with predicted energy savings and eCO_2 reductions.

Table 3: Residential efficiency measures offered by MassSave and renewable generation options

Energy Saving Measure	Annual kWh Saved	Annual Therms Saved	Initial Cost to Customer[23]	Lifetime Savings [24]
MassSave Audit				
CFL's	57	-	$ -	$ 60
Water htg pkg	-	8	$ -	$ 73
Programmable Thermostat	317	75	$ 65	$ 1,451
Refrigerator	879	-	$ 500	$ 1,319
Insulation and Air Sealing	444	338	$ 500	$ 12,637
Heating System Replacement	-	218	$ 4,500	$ 5,101
ES Window	13	3	$ 230	$ 156
Renewable Generation				
Wind Turbine 100	193,000	-	$	$ 579,000

[23] Cost to customer is calculated as cost of measure minus total rebate
[24] Assuming current typical energy costs of $ 0.15/kWh and $1.30/therm
[25] See above

kW			225,000	
PV Installation 3 kW	3,600	-	$ 14,000	$ 16,200

Marshfield has already performed 1,200 audits through MassSave and they will be a continued feature in ongoing efforts to curb emissions in the community. These measures have a significant cumulative effect; the audits already performed account for about 741 tonnes of eCO_2 reductions and a 50% participation rate in the town would result in a savings of about 2.5% in the residential sector (Table 5).

Table 4: Estimated energy and eCO2 savings for every 1000 MassSave audits

Measure	% Participation	Total Annual kWh Savings	Total Annual MMBtu Savings	Total eCO2 Reduction (tonnes)	Total Net Cost	Total Net Benefit[26]
CFL's (avg. 13 installed)	100%	741,000	-	338	$ 778	**$ 59,850**
Water Heating Package	50%	-	4,000	2	$ 36	**$ 72,800**
Programmable Thermostat	25%	79,250	18,750	46	$ 346	**$ 1,385,500**
Refrigerator	10%	87,900	-	40	$ 82	**$ 818,500**
Insulation and Air Sealing	50%	222,000	168,800	191	$ 6,069	**$ 12,137,000**
Total		1,130,150	191,550	617	$ 7,311	**$ 14,473,650**
Average		1,130	192	.617	$ 7.31	**$ 14,473**

[26] Assuming current typical energy costs of $ 0.15/kWh and $1.30/therm

Appendix A: (Return to Table of Contents)

Glossary

AADT – Annual average daily traffic
CACP – Clean Air and Climate Protection
CBECS – Commercial Buildings Energy Consumption Survey
CFL – Compact Fluorescent Light
CHP – Combined heat and power
DEP – Department of Environmental Protection (federal)
DOER – Department of Energy Resources (state)
DPW – Department of Public Works (municipal)
eCO_2 – "equivalent" CO_2
EIA – Energy Information Administration (Federal)
ESCO – Energy Services Company
GHG – Greenhouse gases
IPCC – Intergovernmental Panel on Climate Change
LPG – Liquid petroleum gas
MMA – Massachusetts Municipal Association
PV – Photovoltaic (solar powered electrical generation)
RECS – Residential Energy Consumption Survey
USGCR – United States Global Change Research (federal)
VMT – Vehicle miles traveled

Appendix B:
Contacts

Table B-1: Contact information for data collection

Name	Company/ Department	Email	Phone Number
Derek Buchler	Bay State Gas	dbuchler@nisource. com	508-836-7344
Megan Amsler	Cape & Islands Self-Reliance	megan@reliance.org	508-563-6633
Bonnie Domigan	NSTAR Electric	bonnie.domigan@nstar.com	781-441-8390
Susan Haselhorst	NSTAR Electric	susan.haselhorst@nstar.com	781-441-8702
David Carriere	Marshfield DPW	dcarriere@townofmarshfield.org	781-834-5592
Dr. George Cicchetti	Marshfield Energy Committee	dr.george@verizon.net	617-799-7079

Paul Halkiotis	Marshfield Town Planning	phalkiotis@townofmarshfield.org	781-834-5554
Susan Flynn	Marshfield Accounting	sflynn@townofmarshfield.org	
Martha Totman	Totman Enterprises		781-545-6604

Appendix C:
Emissions Coefficients

Table C-1: Electricity production emissions

Air Emission	Annual Average (lb/MWh)
NOx	0.28
SOx	0.57
CO2[27]	1,004
CH4 [28]	0.08

Appendix D:
Community and Municipal Energy Use Input

Table D-1: Municipal energy use and solid waste generation

Type	Emissions Source	Usage	Units	Cost
Buildings	Electricity	4,784,415	kWh	$ 709,058
	Natural Gas	472,534	Therms	$ 76,899
Vehicle Fleet	Gasoline	100,485.6	gallons	$ 53,482
	Diesel	108,920.5	gallons	$ 56,480
Pumping Stations	Electricity	1,746,333	kWh	$ 84,524
	LP	8,223	gallons	$ 26,561
WW Plant/Pumping	Electricity	2,294,127	kWh	$ 38,370
	Natural Gas	10,720	Therms	$ 15,008
Street Lights	Electricity	276,814	kWh	$ 41,522
Traffic/Misc Lights	Electricity	21,218	kWh	$ 3,321
Airport Lights	Electricity	13,412	kWh	$ 2,658
Solid Waste	Trash	181.41	tons	$ -

Table D-2: Community energy use and solid waste generation

Type	Emissions Source	Usage	Units
Residential	Electricity	81,084,009	kWh
	Natural Gas	7,058,184	Therms
	Fuel Oil	3,757,142	gallons
	LPG	395,489	gallons
	Wood	1,687	cords

[27] http://www.iso-ne.com/genrtion_resrcs/reports/emission/2007_mea_report.pdf
[28] http://www.icleiusa.org/action-center/tools/lgo-protocol-1

Commercial	Electricity	41,948,466	kWh
	Natural Gas	1,805,185	Therms
	Fuel oil	709,156	gallons
Transportation	Collectors/Local	9.29	AADT
	Major Arterial	4.81	AADT
Solid Waste	Trash	7804	tons

Appendix E:
CACP Outputs

Community m**ain outputs**

Table E-1: CACP Community main outputs

Sector	Sector Label	Energy Use (MBtu)	eCO2 (tonnes)
1	Residential	1,693,406	115,673
2	Commercial	1,683,967	97,135
2	Municipal	111,663	8,602
4	Transportation	2,979,895	204,932
5	Waste	-	3,056

Table E-2: CACP Community detailed outputs

Sector	Fuel	Quantity	Units	Energy Use (MBtu)	eCO2 (tonnes)
1	Electricity	81,084,009	(kWh)	291,902	36,988
1	Fuel Oil (#1 2 4)	3,757,142	(US gal)	549,576	38,330
1	Natural Gas	7,058,184	(therms)	744,497	37,547
1	Propane	395,489	(US gal)	37,977	2,286
1	Wood 12% moisture	4,281	(tons)	69,453	523
2	Electricity	37,164,051	(kWh)	133,791	16,953
2	Fuel Oil (#1 2 4)	709,156	(US gal)	103,732	7,235
2	Natural Gas	1,332,651	(thousandft^3)	1,446,445	72,948
2	Electricity	4,784,415	(kWh)	17,224	2,183
2	Natural Gas	472,534	(therms)	49,843	2,514
4	Diesel	-	(vehicle-miles)	477,805	33,168
4	Gasoline	-	(vehicle-miles)	2,502,090	171,764
5	Paper Products	22	(tons)	-	1,911
5	Food Waste	18	(tons)	-	1,456
5	Plant Debris	7	(tons)	-	(79)
5	Wood or Textiles	14	(tons)	-	(231)
5	All Other Waste	39	(tons)	-	-

Municipal

Table E-3: CACP Municipal main outputs

Sector	Sector Label	Group Name	Energy Use (Mbtu)	eCO2 (tonnes)	Cost
1	Buildings/ Facilities	D. Webster ES	4,056.08	264.1	$
1	Buildings/ Facilities	G. Winslow ES	4,942.65	312.9	$
1	Buildings/ Facilities	S. River ES	6,689.05	394.6	$
1	Buildings / Facilities	Town Hall	2,323.92	176.7	$
1	Buildings/ Facilities	F. Brook MS	8,793.08	660.6	$
1	Buildings/ Facilities	Martinson ES	6,818.86	357.5	$
1	Buildings/ Facilities	Marshfield HS	18,170.18	1,326.5	$
1	Buildings/ Facilities	Fire Station S. River St	1,448.50	110.2	$
1	Buildings/ Facilities	Highway Dept	16.38	2.1	$
1	Buildings/ Facilities	Ventress Library	1,539.57	134.1	$
1	Buildings/ Facilities	Animal Shelter	94.53	6.5	$
1	Buildings/ Facilities	Harbor Master	51.35	6.5	$
1	Buildings/ Facilities	Eames Way ES	4,007.67	248.8	$
1	Buildings/ Facilities	Rec. Center	189.14	14.6	$
1	Buildings/ Facilities	Senior Center	1,384.08	107.9	$
1	Buildings/ Facilities	Alamo (records)	84.58	4.5	$
1	Buildings/ Facilities	Fire Station Old Main St	311.05	21.2	$
1	Buildings/ Facilities	Fire Station Massasoit	415.84	25.8	$
1	Buildings/ Facilities	Police Station	1,176.20	99.9	$
1	Buildings/ Facilities	School Admin Blg - Seth Ventress	851.38	52.5	$
1	Buildings/ Facilities	Highway Dept Garage 2	1,342.27	69.7	$
1	Buildings/ Facilities	Boys & Girls Club	640.34	40.9	$
1	Buildings/ Facilities	Scale House	30.43	3.9	$
1	Buildings/ Facilities	Office & Maintenance	73.41	9.3	$
1	Buildings/ Facilities	Main Tip	73.41	9.3	$
1	Buildings/ Facilities	Salt Shed	1.45	0.2	$
1	Buildings/ Facilities	H2O Trailer	45.80	5.8	$
1	Buildings/ Facilities	Main Garage	403.06	51.1	$
2	Streetlights & Traffic Signals	Streetlights	996.53	126.3	$ 4
2	Streetlights & Traffic Signals	Traffic/Misc Lighting	69.87	8.9	$
2	Streetlights & Traffic Signals	Airport Lights	48.28	6.1	$
5	Water Delivery Facilities	Potable water pumps	7,081.60	844.5	$
6	Wastewater Facilities	Waste water pumps	931.31	115.2	$
6	Wastewater Facilities	Treatment Plant	8,458.30	988.3	$
7	Solid Waste		-	71.0	$

8	Vehicle Fleet	Untitled	29,099.19	1,995.9	$	

Table E-4: CACP Municipal detailed outputs

Sector	Fuel	Quantity	Units	Cost	Energy Output (Mbtu)	eCO2 (tonnes)
1	Electricity	216,720	(kWh)	$ 29,336	780	98.9
1	Natural Gas	31,057	(therms)	$ 43,480	3,276	165.2
1	Electricity	231,840	(kWh)	$ 31,348	835	105.8
1	Natural Gas	38,946	(therms)	$ 54,524	4,108	207.2
1	Electricity	208,480	(kWh)	$ 24,227	751	95.1
1	Natural Gas	56,300	(therms)	$ 78,820	5,939	299.5
1	Electricity	216,640	(kWh)	$ 39,471	780	98.8
1	Natural Gas	14,638	(therms)	$ 20,543	1,544	77.9
1	Electricity	790,880	(kWh)	$105,359	2,847	360.8
1	Natural Gas	56,370	(therms)	$ 78,918	5,946	299.9
1	Electricity	49,400	(kWh)	$ 62,763	178	22.5
1	Natural Gas	62,960	(therms)	$ 88,144	6,641	334.9
1	Electricity	1,493,504	(kWh)	$224,026	5,377	681.3
1	Natural Gas	121,289	(therms)	$169,805	12,794	645.2
1	Electricity	135,408	(kWh)	$ 24,141	487	61.8
1	Natural Gas	9,111	(therms)	$ 12,755	961	48.5
1	Electricity	4,550	(kWh)	$ 792	16	2.1
1	Electricity	205,507	(kWh)	$ 37,254	740	93.7
1	Natural Gas	7,582	(therms)	$ 10,615	800	40.3
1	Electricity	6,275	(kWh)	$ 1,302	23	2.9
1	Natural Gas	682	(therms)	$ 955	72	3.6
1	Electricity	14,265	(kWh)	$ 2,785	51	6.5
1	Electricity	169,840	(kWh)	$ 22,432	611	77.5
1	Natural Gas	32,198	(therms)	$ 45,077	3,396	171.3
1	Electricity	18,257	(kWh)	$ 3,485	66	8.3
1	Natural Gas	1,170	(therms)	$ 1,638	123	6.2
1	Electricity	138,640	(kWh)	$ 26,065	499	63.2
1	Natural Gas	8,390	(therms)	$ 11,746	885	44.6
1	Electricity	759	(kWh)	$ 213	3	0.3
1	Natural Gas	776	(therms)	$ 1,086	82	4.1
1	Electricity	20,098	(kWh)	$ 3,945	72	9.2
1	Natural Gas	2,263	(therms)	$ 3,168	239	12.0
1	Electricity	17,737	(kWh)	$3,486	64	8.1
1	Natural Gas	3,337	(therms)	$ 46,146	352	17.8
1	Electricity	147,640	(kWh)	$ 26,213	532	67.3
1	Natural Gas	6,112	(therms)	$ 8,557	645	32.5
1	Electricity	34,852	(kWh)	$ 5,051	125	15.9
1	Natural Gas	6,882	(therms)	$ 9,635	726	36.6
1	Electricity	7,452	(kWh)	$ 1,487	27	3.4
1	Natural Gas	12,471	(therms)	$ 17,459	1,315	66.3

1	Electricity	31,373	(kWh)	$ 6,227	113	14.3
1	Natural Gas	5,000	(therms)	$ 7,000	527	26.6
1	Electricity	8,453	(kWh)	$ 1,321	30	3.9
1	Electricity	20,393	(kWh)	$ 3,059	73	9.3
1	Electricity	20,393	(kWh)	$ 3,059	73	9.3
Sector	Fuel	Quantity	Units	Cost	Energy Output (Mbtu)	eCO2 (tonnes)
1	Electricity	404	(kWh)	$ 61	1	0.2
1	Electricity	12,722	(kWh)	$ 1,908	46	5.8
1	Electricity	111,960	(kWh)	$ 16,794	403	51.1
2	Electricity	19,407	(kWh)	$ 2,911	70	8.9
2	Electricity	13,412	(kWh)	$ 2,911	48	6.1
5	Electricity	1,746,333	(kWh)	$284,524	6,287	47.9
5	Stationary LPG	8,223	(US gal)	$ 26,561	795	113.3
6	Electricity	248,441	(kWh)	$ 32,429	894	1.9
6	Natural Gas	350	(therms)	$ 490	37	933.2
6	Electricity	2,045,686	(kWh)	$305,941	7,364	55.2
6	Natural Gas	10,370	(therms)	$ 14,518	1,094	126.0
7	Carbon Dioxide	71	(tonnes CO2)	$ -	-	71
8	Diesel	-	(US gal)	$256,480	15,932	889.9
8	Gasoline	-	(US gal)	$253,482	13,167	1105.945

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